Anne Arundel County

Public Schools

Support provided by NASA Goddard Education Programs

Earth Space Systems Science

Unit 2: The Atmosphere

Earth/Space Systems Science
Unit II: The Atmosphere

The Coordinator of Science, Anne Arundel County Public Schools, Maryland would appreciate notification if you plan to use all or any of this educational product at sslutksin@aacps.org.

Earth/Space Systems Science
Unit II: The Atmosphere

Description

An important element of the Earth system is climate. Climate (and its short-term version-weather) is one important way to look at the components and interactions of the Earth's system. Global climate history cuts across traditional discipline boundaries and involves each of the components of the Earth System. The atmosphere will give us a starting point for examining the Earth's system- particularly the greenhouse effect, ozone, and a first look at global warming.

In this unit, students focus on the atmosphere- a sphere composed mostly of materials in the gaseous state. The atmosphere is a thin layer of gases that protects the Earth. It may be the most sensitive and changeable of the Earth's spheres. Materials interact among and between the system and subsystems of the atmosphere following the natural laws of forces and energy. Energy flows into the Earth system from the sun and out of the Earth system into space in the form of heat. Matter in the atmosphere cycles through loops. Driven by sunlight and the earth's internal heat, a variety of cycles connect and continually circulate energy and material through the parts of the earth system.

To understand the interactions of the atmosphere, students must build knowledge based on an understanding of gases and the factors that affect the behavior of gases. Students use and extend understanding of how the processes of radiation, convection, and conduction transfer energy through the earth system. The learning activities in this unit help students to apply basic concepts to the study of some atmospheric events.

Students will be introduced to remote sensing in this unit and begin analyzing data collected from satellites.

Key questions for this unit are:

1. How have current technologies extended our knowledge of the Earth-Space system?
2. What is the composition and structure of the atmosphere?
3. Why does air move?
4. What is Earth's energy budget and what are some of its implications?
5. How does cloud cover influence climate?
6. How have humans influence the concentration and distribution of stratospheric ozone?

Earth/Space Systems Science
Unit II: The Atmosphere

Key Concepts

- Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. (NSES, p. 189)

- Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

- Weather and climate involve the transfer of energy in and out of the atmosphere. Solar radiation heats the landmasses, oceans, and air. (AAAS, p. 70)

- Transformation of energy usually produces some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it. (AAAS, p. 86)

- Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy form hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels. (NSES, p. 180)

- Energy transfer from the sun and near the Earth's surface determines global climate. Dynamic processes such as cloud cover, and earth's rotation and static conditions such as position of mountain ranges and oceans influence this energy transfer. (NSES, p. 189)

Earth/Space Systems Science
Unit II: The Atmosphere

CONTENT OUTLINE

The Atmosphere

I. Matter in the Atmosphere
   A. Atmospheric composition
      1. greenhouse gases
      2. stratospheric ozone
         a) concentration and distribution
      3. particulates
   B. Atmosphere structure
      1. temperature gradients
      2. pressure gradients
      3. cloud cover
         a) amount
         b) type
         c) albedo

II. Atmospheric Circulation
   A. Heat transfer systems
      1. conduction
      2. convection
      3. radiation
      4. latent heat
      5. phase change
   B. Global Circulation
      1. pressure
      2. temperature
      3. volume
      4. Coriolis effect

Earth/Space Systems Science
Unit II: The Atmosphere

LESSON	TITLE	STUDENT OUTCOME (S)	TIME (FIFTY MINUTE BLOCKS)
1	COMPOSITION AND STRUCTURE OF THE ATMOSPHERE	THE STUDENT WILL BE ABLE TO DESCRIBE THE STRUCTURE AND COMPOSITION OF THE ATMOSPHERE BY GRAPHING AND ANALYZING DATA AND READING A TECHNICAL SELECTION.	TWO
2	RADIATION, CONDUCTION, AND CONVECTION	THE STUDENT WILL BE ABLE TO DESCRIBE THE ROLES OF RADIATION, CONDUCTION, AND CONVECTION IN HEAT TRANSFER BY ANALYZING DATA FROM LABORATORY INVESTIGATIONS.	TWO
3	INTRODUCTION TO REMOTE SENSING	THE STUDENT WILL BE ABLE TO DESCRIBE THE PURPOSE AND ADVANTAGE OF REMOTE SENSING BY CREATING AND ANALYZING IMAGES.	TWO
4	REMOTE SENSING – ANALYSIS OF OZONE	1. THE STUDENT WILL BE ABLE TO ILLUSTRATE THE CONCENTRATION AND DISTRIBUTION OF STRATOSPHERIC OZONE BY GRAPHING AND ANALYZING TOMS SATELLITE DATA. 2. THE STUDENT WILL BE ABLE TO EVALUATE THE EFFECTS OF AEROSOLS ON THE CONCENTRATION OF STRATOSPHERIC OZONE BY READING A TECHNICAL PASSAGE.	TWO
5	ALBEDO	THE STUDENT WILL BE ABLE TO EXPLAIN ALBEDO AND DESCRIBE ITS EFFECT ON HEAT ABSORPTION BY CONDUCTING LABORATORY INVESTIGATIONS.	TWO

6	CLOUDS	THE STUDENT WILL BE ABLE TO COMPARE TYPES OF CLOUDS BY ANALYZING THEIR CHARACTERISTICS. THE STUDENT WILL BE ABLE TO EXPLAIN THE IMPACT OF CLOUD COVER ON WEATHER BY READING A TECHNICAL SELECTION.	ONE
7	FACTORS THAT INFLUENCE EARTH'S ENERGY BUDGET	THE STUDENT WILL BE ABLE TO INTERPRET EARTH'S ENERGY BUDGET BY ANALYZING THE EFFECTS OF CLOUD COVER, GREENHOUSE GASES, AND PARTICULATES.	THREE
8	THE CORIOLIS EFFECT	THE STUDENT WILL BE ABLE TO DESCRIBE HOW THE CORIOLIS EFFECT INFLUENCES ATMOSPHERIC CIRCULATION BY ANALYZING THE RESULTS OF A LABORATORY INVESTIGATION.	ONE
9	CONVECTION CELLS	1. THE STUDENT WILL BE ABLE TO DIAGRAM ATMOSPHERIC CONVECTION CELLS BY CONDUCTING A LABORATORY INVESTIGATION AND READING A TECHNICAL SELECTION. 2. THE STUDENT WILL BE ABLE TO EXPLAIN HOW WINDS MODERATE WEATHER AND CLIMATE BY ANALYZING THE PATTERN OF GLOBAL WINDS.	TWO
10	PRESSURE GRADIENTS	THE STUDENT WILL BE ABLE TO EVALUATE THE RELATIONSHIP BETWEEN PRESSURE GRADIENTS AND WIND SPEED BY ANALYZING WEATHER MAPS.	ONE

Earth/Space Systems Science
Unit II: The Atmosphere

11	Latent Heat and Storms	1. The student will be able to explain how latent heat contributes to the formation of storms by examining the life cycle of a thunderstorm. 2. The student will be able to describe the role of satellites in meteorology by analyzing satellite imagery.	One
	Benchmark Assessment		One
Approximate Number of Time Blocks			20

Earth/Space Systems Science
Unit II: The Atmosphere

MATERIALS PAGE (1 OF 2)

Aluminum foil	Hot water bath
Baby food jar	Ice
Balloons	Isobar/ pressure data maps
Barometric pressure and altitude data table	Lamps
Beakers, assorted sizes	Markers
Bottles, 2 L soda clear plastic with cap	Matches
Calculators	Meter stick
Candle	Newsprint
Light probes	Paper, colored, black, white
Temperature probe	Pen, felt
CBLs or computers for data collection	Pencils, colored
Clamps	Pressure data maps
Compact fluorescent light source	Ruler
Construction paper, colored	Soil, dark dry
Convection box: · Convection of Gas Apparatus Fisher CDS41795 · Gas Convection Apparatus Sargent Welch CP77590-00	Spectroscope
· Coriolis Effect Kit Fisher CDS53088 · Coriolis Effect Wheel and Foucault Pendulum Sargent Welch WLO934A (optional) Phonograph or Lazy Susan may be substituted for above	Stopper, one-hole
Erlenmeyer flask, small	Straw
Experimental design sheet	Tape, transparent
Flashlight	Temperature and altitude data table

Flexible foam or cotton wadding	Thermometers
Food coloring	Topographic map
Globe	Transparency sheets
Graph paper	Water
Gray scale cards	White foam board
Hot plate	Wooden splint

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 1: COMPOSITION AND STRUCTURE OF THE ATMOSPHERE

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.1 The student will organize data appropriately using techniques such as tables, graphs, and webs (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title).

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

Indicator(s): Core Learning Goal 2:

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits (at least) –Atmospheric composition and structure (greenhouse gases, stratospheric ozone concentration and distribution, aerosols, temperature)

Student Outcome(s):

The student will be able to describe the structure and composition of the atmosphere by graphing and analyzing data and reading a technical selection.

WHAT DOES THE RESEARCH SAY?

Plants alter the earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air. National Research Council, *National Science Education Standards* (1996).

Earth/Space Systems Science
Unit II: The Atmosphere

Brief Description:

In this lesson, students graph barometric pressure, temperature, and altitude. They use this information to predict the structure and composition of the atmosphere. After reading a technical selection, students draw and label a diagram of the atmosphere.

Background knowledge / teacher notes:

Barometric pressure drops gradually with increasing altitude in the lower and middle troposphere, but drops very rapidly with increased altitude in layers above the troposphere. Gravity is the natural force that retains Earth's atmosphere. Since barometric pressure is the weight of air, most of the air in the atmosphere is located in the lower to middle portions of the troposphere.

The atmosphere is divided into layers based on temperature characteristics. Most references refer to the layers as troposphere, stratosphere, mesosphere and the thermosphere. Students may also come across the term ionosphere. *Ionosphere* is a term that combines the mesosphere and the thermosphere into one layer consisting of charged particles (ions). The boundaries between the layers are the tropopause, the stratopause and the mesopause.

Excluding water vapor, which varies significantly, the troposphere is composed of 78% nitrogen (N_2) and 21% oxygen (O_2). The remaining one percent is mainly composed of argon and carbon dioxide. The stratosphere (the location of the ozone layer) is mostly composed of ozone (O_3). The mesosphere and thermosphere contain concentrations of nitrogen and oxygen ions.

Temperatures decrease with altitude in the troposphere, increase in the stratosphere, decrease in the mesosphere, and then increase in the thermosphere. All clouds are located at various altitudes in the troposphere.

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson Description:

<table>
<tr><td>ENGAGE</td><td>
Teacher demonstration: Take a deep breath and blow into a balloon.
Discussion:
1. What's in the balloon? air
2. What gases are in the balloon? Oxygen, carbon dioxide…
Write the responses on the board or overhead
3. Brainstorm the gases in air.
4. Which gas is most abundant?
<table>
<tr><th>Gas Name</th><th>Chemical Formula</th><th>Percent Volume</th></tr>
<tr><td>Nitrogen</td><td>N_2</td><td>78.08%</td></tr>
<tr><td>Oxygen</td><td>O_2</td><td>20.95%</td></tr>
<tr><td>*Water</td><td>H_2O</td><td>0 to 4%</td></tr>
<tr><td>*Carbon Dioxide</td><td>CO_2</td><td>0.0360%</td></tr>
<tr><td>*Ozone</td><td>O_3</td><td>0.000004</td></tr>
</table>
Teacher Note: There are other gases, but these are the most critical to understanding the basic composition of the atmosphere.

Discussion:
1. When you are going up or down a mountain or swimming underwater, how are your ears affected? They pop.
2. Why do your ears pop? There is a difference in pressure inside the ear and outside the ear. The pop equalizes the pressure.
3. What is air pressure? Air pressure is caused by the weight of the air pressing down on earth.
4. How do we measure air pressure? What does the weatherman say? Barometric pressure is rising or falling

Working in groups, students build a bottle barometer.
Build a Bottle Barometer
Materials: rigid container such as an Erlenmeyer flask or baby food jar,
</td></tr>
</table>

	one-hole stopper to fit flask, a straw or tube, water, food coloring, felt pen, ruler Directions: 1. Fill flask _ full of colored water. 2. Add stopper, but do not seal tightly! 3. Place straw in the stopper so that it almost touches the bottom of the flask. 4. Straw should extend well above the top of the stopper. 5. Using a ruler, mark one-centimeter increments on the straw. 6. Inhale through the straw until the water level is above the stopper. 7. Quickly push on the stopper and seal it into the flask. 8. Record the starting barometric pressure in the data table. 9. Press on the stopper, what happens to the pressure? 10. Release the stopper, what happens to the pressure? 11. In small groups discuss why the pressure changed. What factors might cause changes in barometric pressure? ***Journal Write:*** 1. Why did the pressure change? 2. What factors might cause changes in barometric pressure? 3. Design a data table to record changes in the barometric pressure over the next few days.
EXPLORE	In small groups, predict how barometric pressure might change with altitude. What factors might influence the amount of air/barometric pressure? ***Journal Write:*** Technical Connection: 1. Graph the data in the table “Barometric Pressures and Altitude” using a graphing program such as NCES. *Create a Graph*. Available: http://nces.ed.gov/nceskids/graphing/ or Excel

	2. Graph the data in the table "Temperature and Altitude" using a graphing program such as NCES. *Create a Graph*. Available: http://nces.ed.gov/nceskids/graphing/ or Excel Adaptive Strategy: Discuss the type of graph best suited for the data.
EXPLAIN	Working in small groups, discuss how barometric pressure changes with altitude. Examine the graph. Describe how temperature changes with altitude. ***Journal Write:*** 1. How does barometric pressure change with altitude? 2. What does this indicate about the structure of the atmosphere? 3. Describe the temperature changes that occur with altitude. 4. What might this indicate about the composition of the atmosphere?
EXTEND	Read to be informed about the structure and composition of the atmosphere. Design a graphic organizer to record the information about the structure and composition of the atmosphere. Draw and label a diagram of the atmosphere. Technical Reading Teacher Note: This site has three different reading levels. Windows on the Universe. *Layers of the Earth.* Available: http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/layers.html NASA. *Liftoff Earth's Atmosphere.* Available: http://liftoff.msfc.nasa.gov/academy/space/atmosphere.html

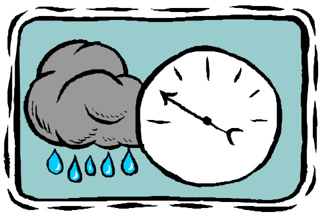
	Discussion: 1. As a class draw and label a diagram of the atmosphere. NASA. Studying Earth's Environment from Space. *Graph of Atmospheric layers.* http://see.gsfc.nasa.gov/edu/SEES/globa/class/Chap_1/1_Js/1-02.jpg EAO Scientific Systems. *Temperature Profile of the Atmosphere.* Available: http://www.eoascientific.com/interactive/mesosphere_stratosphere_thermosphere/mesosphere_stratosphere_thermosphere.html 2. Why does the temperature change from one layer to the next? *The ozone molecules in the stratosphere absorb high-energy UV rays from the sun, which warm the atmosphere. In the mesosphere, the air masses are relatively mixed together so temperature decreases with altitude. The thermosphere is exposed to the Sun's radiation and is heated by the Sun. The air is so thin that a small increase in energy can cause a large increase in temperature.* Adaptive Strategy: If students have difficulty understanding how temperature affects the movement of molecules, there is a good simulation of this effect. University of California at Irvine Chemistry. *The Ideal Atmosphere.* Available: http://www.chem.uci.edu/education/undergrad_pgm/applets/canonical/canonical.htm ***Journal Write:*** 1. Why does the temperature change so much from one layer to the next? *The ozone molecules in the stratosphere absorb high-energy UV rays from the sun, which warm the atmosphere.*

	In the mesosphere, the air masses are relatively mixed together so temperature decreases with altitude. *The thermosphere is exposed to the Sun's radiation and is first heated by the Sun. The air is so thin that a small increase in energy can cause a large increase in temperature.* Career Connection: National Weather Service. *A Typical Day in the Life of a National Weather Service Employee.* Available: http://www.nws.noaa.gov/er/phi/tour/gary.html
EVALUATE	***Journal Write:*** Using your graphic organizer, write a brief paragraph describing the structure and composition of the atmosphere. Be sure to describe changes in barometric pressure and temperature. Use evidence from your graphs to support your answer.

Materials:

- Erlenmeyer flask or baby food jar
- One-hole stopper
- Straw or tube
- Water
- Food coloring
- Felt pen
- Ruler
- Barometric pressure and altitude data table
- Temperature and altitude data table
- Graph paper

Build a Bottle Barometer



Materials: rigid container such as Erlenmeyer flask or baby food jar, one-hole stopper to fit flask, a straw or tube, water, food coloring, felt pen, ruler

Make notes and answer questions in your journal.

Directions:

1. Fill container _ full of colored water.
2. Add stopper, but do not seal tightly!
3. Place straw in the stopper so that it almost touches the bottom of the flask. The straw should extend well above the top of the stopper.
4. Using a ruler, mark one cm increments on the straw.
5. Inhale through the straw until the water level is above the stopper.
6. Quickly push on the stopper and seal it into the flask.
7. Record the starting barometric pressure in the data table.
8. Press on the stopper. Describe what happens to the pressure.
9. Release the stopper. Describe what happens to the pressure.

BOTTLE BAROMETER

Use any rigid, narrow-mouthed container. The greater the internal volume of the container, the more responsive it will be to changes.

Glass tube, or plastic straw.

The smaller the bore of the tube or straw, the more responsive the barometer will to be changes.

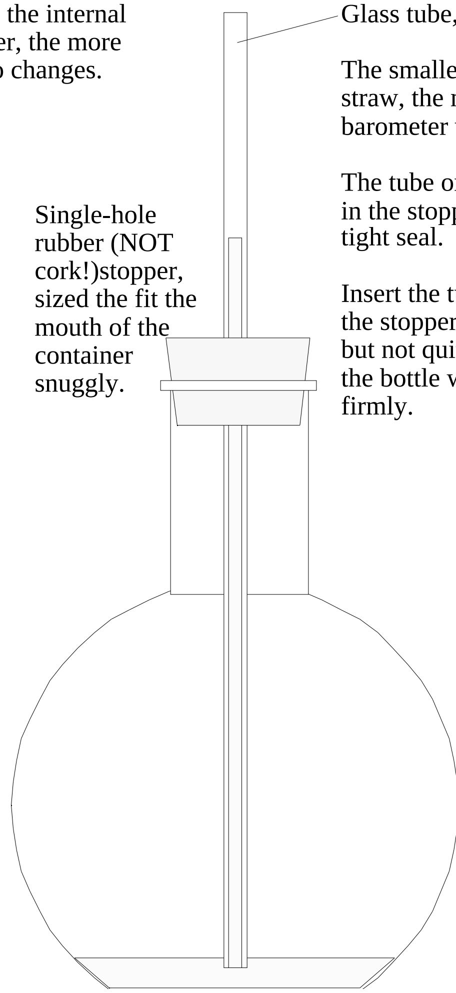
The tube or straw must fit the hole in the stopper firmly, with an air-tight seal.

Single-hole rubber (NOT cork!)stopper, sized the fit the mouth of the container snuggly.

Insert the tube far enough through the stopper so that it will almost – but not quite – touch the bottom of the bottle when the stopper is seated firmly.

A *rise* in the level of water in the tube indicates:
- An increase of air pressure in the container. Or:
- A decrease of air pressure outside of the container.
- An increase in temperature of the gas in the container.

A *fall* in the level of water in the tube indicates one of the opposite conditions.



If the bore of the tube is small enough, the water will rise above the level of the stopper as the stopper is being seated. If not, draw the water higher into the tube, before completely seating the stopper.

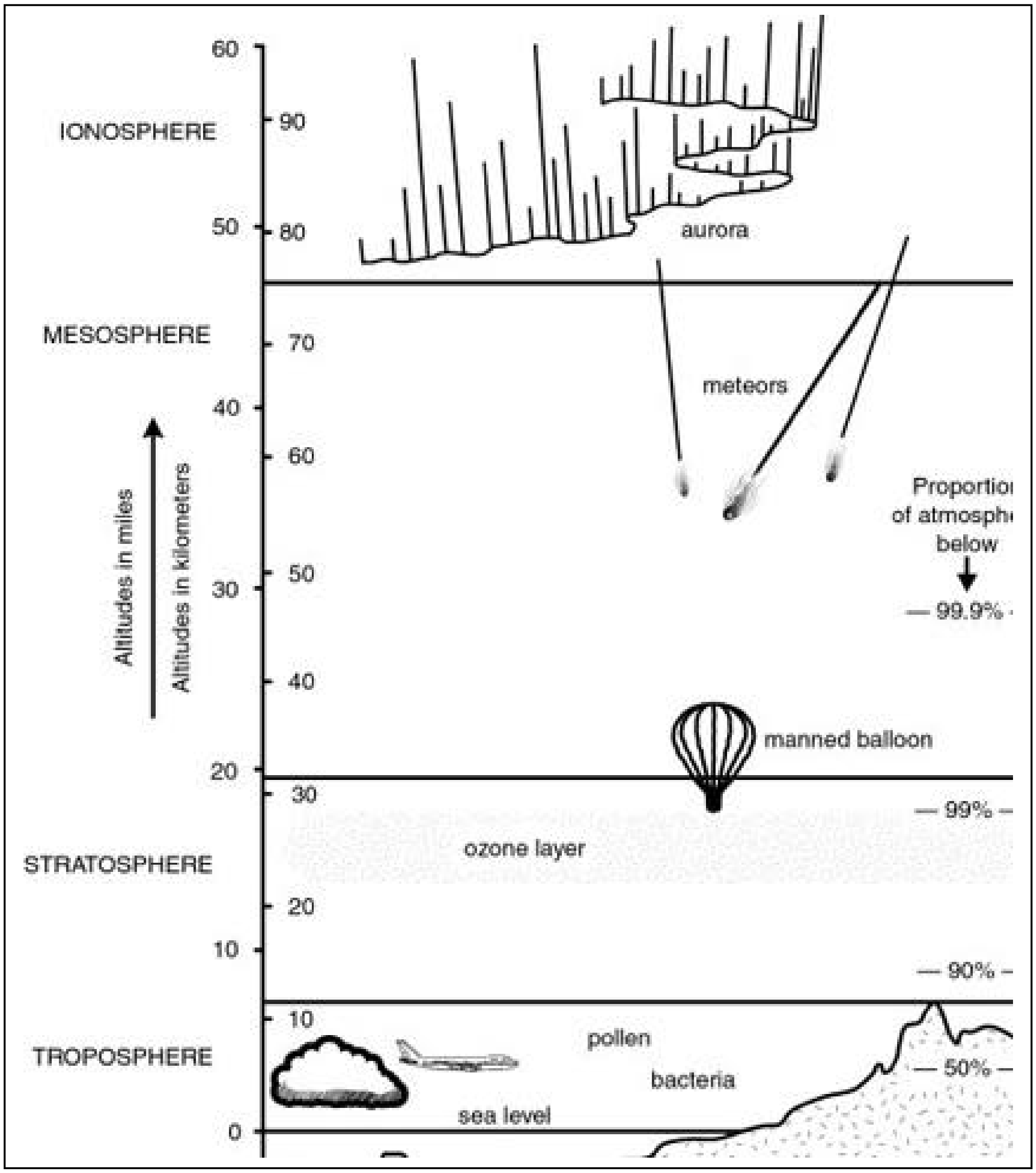
Colored water. Pour in just enough water so that it will cover the oppening in the bottom of the tube.

Barometric Pressures and Altitude

Altitude (Kilometers)	Average Barometric Pressure (Millibars)
0	1000
2	800
6	425
10	275
14	150
18	100
22	50
26	30
30	25
36	25

Temperature and Altitude

Altitude (Kilometer)	Temperature (°Celsius)
5	4.5
6	-5.9
8	-16.1
9	-27.6
11	-39.8
12	-50.2
14	-62.9
20	-67
25	-58
32	-50
40	-24
50	0
60	-20
82	-90
90	-90
101	-80
108	-40
120	90



NASA. Studying Earth's Environment from Space. *Graph of Atmospheric layers.*

http://see.gsfc.nasa.gov/edu/SEES/globa/class/Chap_1/1_Js/1-02.jpg

Resources:

National Weather Service. *A Typical Day in the Life of a National Weather Service Employee.*
Available: http://www.nws.noaa.gov/er/phi/tour/gary.html

NCES. *Create a Graph*.
Available: http://nces.ed.gov/nceskids/graphing/

NASA. Studying Earth's Environment from Space. *Graph of Atmospheric layers. Image.*
http://see.gsfc.nasa.gov/edu/SEES/globa/class/Chap_1/1_Js/1-02.jpg

Windows on the Universe. *Layers of the Earth.*
Available: http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/layers.html

NASA. *Liftoff Earth's Atmosphere.*
Available: http://liftoff.msfc.nasa.gov/academy/space/atmosphere.html

EAO Scientific Systems. *Temperature Profile of the Atmosphere.*
Available:
http://www.eoascientific.com/interactive/mesosphere_stratosphere_thermosphere/mesosphere_stratosphere_thermosphere.html

University of California at Irvine Chemistry. *The Ideal Atmosphere.*
Available: http://www.chem.uci.edu/education/undergrad_pgm/applets/canonical/canonical.htm

Earth/Space Systems Science
Unit II: The Atmosphere

LESSON 2: RADIATION, CONDUCTION AND CONVECTION

Estimated Time: Two fifty-minute blocks

Indicator(s) Core learning Goal 1:

1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

Indicator(s): Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) -Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

Student Instructional Outcome(s):

The student will be able to describe the roles of radiation, conduction, and convection in heat transfer by analyzing data from laboratory investigations.

WHAT DOES THE RESEARCH SAY?

Students use and extend their understanding of how the processes of radiation, convection, and conduction transfer energy through the earth system.

National Research Council, *National Science Education Standards* (1996).

Brief Description:

Earth/Space Systems Science
Unit II: The Atmosphere

Students model the action of solar radiant energy heating the atmosphere and Earth's surface. They simulate the role of conduction and convection in transferring heat energy from Earth's surface throughout the atmosphere. Students develop a systems diagram illustrating heat transfer through Earth's atmosphere.

Background knowledge / teacher notes:

Radiant energy (radiation) from the Sun heats the surface of the Earth by transferring energy to matter that is opaque. Since air is transparent, most of the radiation (light) from the Sun passes through only moderately heating the air. But the ground is completely opaque; all of the radiation that strikes the ground (and is not reflected) is absorbed right at the surface and (mostly) turned into heat energy.

Conduction transfers heat from the warmer surface to the cooler air by direct contact. Through convection, heated air expands, becomes less dense (and thus more buoyant) and rises, transporting the heat energy vertically through the air column. The uneven heating generates winds that transports heat energy horizontally. Radiation, convection, and conduction are the major processes governing Earth's energy budget.

This website contains several PowerPoint presentations with wonderful graphics about the atmosphere. Scott Pike. Lynchburg College. *Courses.*

Available: http://pike_s.web.lynchburg.edu/

Lesson Description:

ENGAGE	If it is a nice, sunny day, take the students outside with thermometers. Have one group stand in direct sunlight and record the temperature directly about the ground. Have the other group stand in a shady spot and record the temperature directly about the ground. (Alternatively, you can set up bright lamps in your classroom, and adapt these activities.)

	Discussion: 1. How did the temperature differ between these two spots? 2. Why did the temperature differ? *Sunlight or solar radiation is warming the air*
EXPLORE	How does sunlight warm the air? Materials per lab group: two, two liter clear plastic soda bottles, light or natural sunlight, two temperature sensors, CBL, or two thermometers, dark soil, matches, wooden splint**,** flexible foam or cotton wadding**,** transparent tape, aluminum foil, ruler Show students the experimental set up. How often should we take temperature readings? Teacher Note: Experiment runs faster outside in direction sunlight (10 minutes). In the classroom, it takes 20-30 minutes. ***Journal Write:*** · Design a data table to record temperature changes in both bottles over time. Directions for building apparatus: Part One: 1. Measure at least five cm from the bottom of the bottles. 2. At this level, cut a slit or punch several holes. Do this on both sides of the bottles. 3. Cover holes/slits with clear tape. 4. Cover the bottom of one of the bottles with dark soil. 5. Cut a small piece of aluminum foil. Tape this piece of aluminum to the thermometer or temperatures sensor so that is shades the bulb. Do this for both thermometers/temperature sensors. 6. Place one thermometer/temperature sensor in each of the bottles.

	Suspend them above the slits by packing cotton wadding or flexible foam around the opening at the top. Make sure it's not airtight! 7. Place the bottles on ring stands or on foam board side-by-side directly under the light source. 8. Record the temperature data at specific time intervals. Teacher Note: Do not put bottles directly on the ground. Conduction from the ground will interfere with the experiment. Part Two: 9. Remove the wadding from the top, but not the thermometer/temperature sensor, and the tape that was covering the slits in the sides of the bottles. 10. Place your hand over the opening. Record your observations in the data table. 11. Continue recording the temperature. Part Three: 12. Recover one of the slits with tape. 13. Ignite a wooden splint. Count to ten. 14. Extinguish the flame. 15. Hold the smoking end of the splint near an open slit
EXPLAIN	***Journal Write:*** 1. Use a graphing program such as NCES. *Create a Graph.* Available: http://nces.ed.gov/nceskids/graphing/ or Excel to graph the data. 2. Describe the changes in temperature over time. 3. Compare the temperature changes in the bottle with soil to the bottle without soil. 4. Why did the smoke rise? *The smoke followed the flow of heat tracing the path of convection currents.* 5. Draw a picture of the experimental set up. Use arrows to trace the flow of energy through the system. *The temperature of the air in*

	both containers will rise. However, the temperature of the air in the container with the layer of soil will increase more rapidly and reach a higher temperature. The air and the containers are both relatively transparent to light. Therefore, they will absorb relative little energy. The soil is opaque; the radiant energy is absorbed at the soil surface, which heats up. The soil heats the air by conduction. Convection distributes the heated air through the container. Discussion: 1. Trace the flow of energy through the system. 2. Explain how energy flowed through the systems using radiation, conduction, and convection. <u>Adaptive Strategy:</u> Illustrate how conduction heats the atmosphere through this simulation. University of California. Irvine. *The Ideal Atmosphere.* Available: http://www.chem.uci.edu/education/undergrad_pgm/applets/canonical/canonical.htm *The bouncing balls are an analogy; the air molecules do not actually behave that way.* *With molecules, speed = temperature; the faster the molecules are moving, the hotter they are (the more heat energy they have absorbed).* *The bar graph along the right margin of the animation is indicating the average velocity (=temperature) of the molecules at the different altitudes.* ***Journal Write:*** 1. Label the parts of the container that demonstrate radiation, conduction, and convection. 2. Why did the temperature decrease after the wadding was removed?

	Convection caused the heated air to leave through the top.
EXTEND	Why does hot air rise? Materials: Small Erlenmeyer flask, balloon, two large beakers, ice, hot plate or hot water bath. ***Journal Write:*** · Write a hypothesis to explain why hot air rises. · Design experimental procedures to test your hypothesis · Design a data table to record the size of the balloon. Sample Procedure: 1. Fill a large beaker half way with water and place on hot plate. 2. Heat water until hot, but not boiling. 3. Fill a second large beaker half way with ice. 4. Cap the Erlenmeyer flask with a balloon. 5. Place the flask in hot water. 6. Observe the balloon for a few minutes. Record your observations in your data table. 7. Carefully remove the flask from the hot water and place in the beaker with ice. 8. Observe the balloon for a few minutes. Record your observations in your data table. In small groups discuss your observations. 1. Why did the balloon inflate when placed in hot water? *As the air's volume increases in the warm water, the balloon inflates;* 2. Why did the balloon deflate when placed in cold water? *As the air's volume decreases in the cold water, the balloon deflates.* ***Journal Write:*** · What is the relationship between temperature and volume?

	As temperature increases, volume increases. Teacher Note: the PowerPoint referred to in the background notes, contains slides sequences covering these topics. Scott Pike. Lynchburg College. *Courses.* Available: http://pike_s.web.lynchburg.edu/ pike_s.web.lynchburg.edu/211/ CH.4%20 %20insolation%20and%20temperature.ppt G/T/ Technical Connection: ISU. Department of Chemistry. *Chemistry Experiment Simulations, Tutorials and Conceptual Computer Animations.* Available: http://www.chem.iastate.edu/ChemEdGroup/GREENBOWE/sections/projectfolder/animationsindex.htm. Scroll down to the Gas Laws section to · Boyle's Law experiment no graphs (student version) · Charles' Law Charles' Law Experiment - simulation 2.3.02 ***Journal Write:*** 1. Describe the relationship between temperature and volume. 2. Describe the relationship between volume and pressure. Read to be informed about radiation, conduction, and convection. Record the information in a graphic organizer. Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. *Atmosphere: Solar Fundamentals.* pp. 275 –277. Or Physics Department. University of Winnipeg. *Heat Transfer.* Available: http://theory.uwinnipeg.ca/mod_tech/node74.html Or other similar texts.

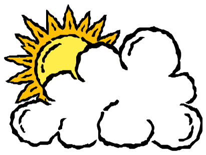
	Journal Write: Technical Connection: View the animation at FemLab. Mulitphysics in MatLab. *Heat Flow in a Room.* http://www.femlab.com/showroom/animations/ · Explain how heat is transferred throughout the room. Discussion: How is energy from the sun transferred throughout Earth's atmosphere? INTEREST CENTER How do hot air balloons work? MarshallBrain. How Stuff Works. *How Hot Air Balloons Work.* Available: http://www.howstuffworks.com/hot-air-balloon.htm/printable
EVALUATE	***Journal Write:*** Working in pairs, construct a systems diagram illustrating the transfer of heat through Earth's atmosphere. Be sure to include the terms radiation, conduction, and convection.

Materials:

- 2 L soda bottles, clear plastic
- Temperature sensor
- CBL
- Thermometers
- Dark dry soil
- Light
- Flexible foam or cotton wadding
- Transparent tape
- White foam board

- Retort stand
- Clamps
- Wood splints
- Matches
- Small Erlenmeyer flask
- Balloons
- Large beakers
- Ice
- Hot plate
- Hot water bath

Earth/Space Systems Science
Unit II: The Atmosphere

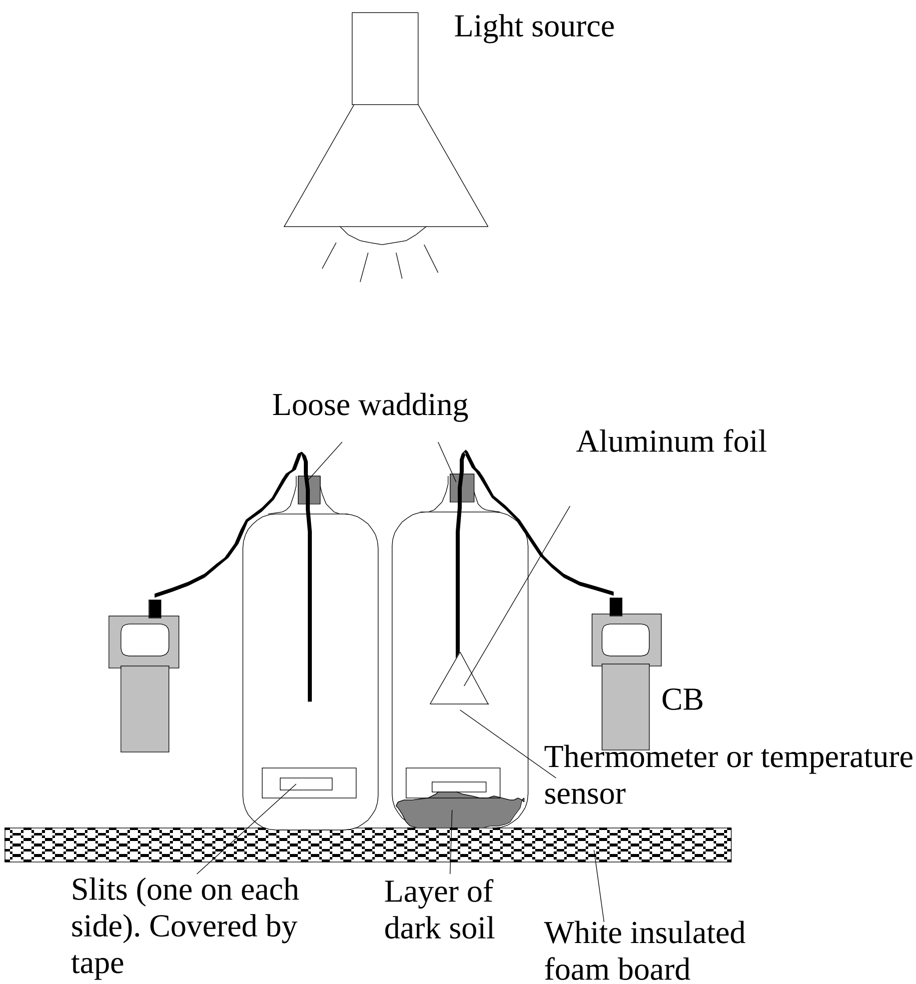


How does sunlight warm the air?

Materials per lab group: two, two liter clear plastic soda bottles, light or natural sunlight, two temperature sensors, CBL, or two thermometers, dark soil, matches, wooden splint, flexible foam or cotton wadding, transparent tape, aluminum foil, ruler

Journal Write:

Design a data table to record temperature changes in both bottles over time.



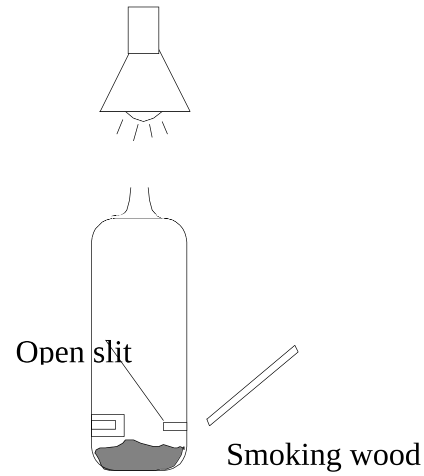
Directions:

Part One:

1. Measure at least five cm from the bottom of the bottles.
2. At this level, cut a slit or punch several holes. Do this on both sides of the bottles.
3. Cover holes/slits with clear tape.
4. Cover the bottom of one of the bottles with dark soil.
5. Cut a small piece of aluminum foil. Tape this piece of aluminum to the thermometer or temperatures sensor so that is shades the bulb. Do this for both thermometers/temperature sensors.
6. Place one thermometer/temperature sensor in each of the bottles. Suspend them above the slits by packing cotton wadding or flexible foam around the opening at the top. Make sure it's not airtight!
7. Place the bottles on ring stands or on foam board side-by-side directly under the light source.
8. Record the temperature data at specific time intervals.

Part Two:

9. Remove the wadding from the top, but not the thermometer/temperature sensor, and the tape that was covering the slits in the sides of the bottles.
10. Place your hand over the opening. Record your observations in the data table.
11. Continue recording the temperature.



Part Three:

12. Recover one of the slits with tape.
13. Ignite a wooden splint. Count to ten.
14. Extinguish the flame.
15. Hold the smoking end of the splint near an open slit

Journal Write:

1. Use a graphing program such as NCES. *Create a Graph*. Available: http://nces.ed.gov/nceskids/graphing/ or Excel to graph the data.
2. Describe the changes in temperature over time.
3. Compare the temperature changes in the bottle with soil to the bottle without soil.
4. Why did the smoke rise?
5. Draw a picture of the experimental set up. Use arrows to trace the flow of energy through the system.

Resources:

Scott Pike. Lynchburg College. *Courses.*
Available: http://pike_s.web.lynchburg.edu/

NCES. *Create a Graph.*
Available: http://nces.ed.gov/nceskids/graphing/

Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Atmosphere: Solar Fundamentals." pp. 275 –277.

FemLab. Mulitphysics in MatLab. *Heat Flow in a Room.*
http://www.femlab.com/showroom/animations/

Physics Department. University of Winnipeg. *Heat Transfer.*
Available: http://theory.uwinnipeg.ca/mod_tech/node74.html

University of California. Irvine. *The Ideal Atmosphere.*
Available: http://www.chem.uci.edu/education/undergrad_pgm/applets/canonical/canonical.htm

INTEREST CENTER

MarshallBrain. How Stuff Works. *How Hot Air Balloons Work.*
Available: http://www.howstuffworks.com/hot-air-balloon.htm/printable

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 3: INTRODUCTION TO REMOTE SENSING

Estimated Time: Two fifty-minute blocks

Indicators(s): Core Learning Goal 1

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.2 The student will explain scientific concepts and processes through drawing, writing, and/or oral communication.

1.5.4 The student will create and/or interpret graphics (scale drawings, photographs, digital images, etc.).

1.5.9 The student will communicate conclusions derived through a synthesis of ideas.

1.7.6 The student will explain how development of scientific knowledge leads to the creation of new technology and how technological advances allow for additional scientific accomplishments.

Indicators(s): Core Learning Goal 2

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth.
Assessment limits (at least) –Tools (spectrometers, seismograph), Delivery systems (satellite-based, ground-based), Techniques (imaging, Geographic Information System, Global Positioning System, spectroscopy, Doppler, epicenter location/time-travel graphs)

Student Outcome(s):

The student will be able to describe the purpose and advantage of remote sensing by creating and analyzing images.

Earth/Space Systems Science
Unit II: The Atmosphere

WHAT DOES THE RESEARCH SAY?

Because direct experimentation is usually not possible for many concepts associated with earth and space science, it is important to maintain the spirit of inquiry by focusing the teaching on questions that can be answered by using observational data, the knowledge base of science, and processes of reasoning. *National Science Education Standards* (1996).

In the course of solving any problem where students try to meet certain criteria within constraints, they will find that the ideas and methods of science that they know, or can learn, can be powerful aids. Students also find that they need to call on other sources of knowledge and skill, such as cost, risk, and benefit analysis, and aspects of critical thinking and creativity. Learning experiences associated with this standard should include examples of technological achievement in which science has played a part and examples where technological advances contributed directly to scientific progress. *National Science Education Standards* (1996).

Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. *National Science Education Standards* (1996).

Brief Description:

Students explore the technology and applications of remote sensing. They create a public service announcement explaining how this technology allows scientists to gather data about Earth's spheres.

Background knowledge / teacher notes:

Satellite images of Earth's atmosphere, hydrosphere, lithosphere, and biosphere have proved to be valuable tools for studying the complexity of Earth's environmental systems. Earth observing satellites routinely monitor rapidly changing weather, El Nino-Southern Oscillation phenomena in the Pacific Ocean, ocean currents, land and oceanic vegetation, polar sea ice distribution, and stratospheric ozone depletion.

Earth/Space Systems Science
Unit II: The Atmosphere

For additional teacher information, visit NASA GSFC. *Stratospheric Ozone and Global Land Vegetation Modules*.
Available: http://see.gsfc.nasa.gov/edu/SEES/#who

Lesson Description:

ENGAGE	Show students a photograph of Earth taken from space. One example can be found at University of Hawaii. *Shuttle Photographs.* Available: http://mael.soest.hawaii.edu/space/hawaii/images/bigisle/island.shuttle.425x395.gif Discussion 1. What does this picture show? *a view of Earth, landmass* 2. Where was this picture taken? *from space* 3. What technology is needed for this type of picture? *spacecraft, satellite, remote sensing*
EXPLORE	Technical Connection: Read to be informed about remote sensing. University of Hawaii. *Virtually Hawaii.* Available: http://mael.soest.hawaii.edu/space/hawaii/index.html Follow links to Remote Radar Tutorial, or access the site directly: University of Hawaii. *Introduction to Remote Radar Sensing.* Available: http://satftp.soest.hawaii.edu/space/hawaii/vfts/kilauea/radar_ex/intro.html Adaptive Strategy: After the students have read page one, skip to page six "What can we see in a radar image?" Explain how the image was formed and help them interpret the image. Be sure to compare images with the ground photos found on page seven.

EXPLAIN	***Journal Write:*** Create a graphic organizer summarizing information on remote sensing. 1. Compare radar to visible and infrared sensors. 2. Compare satellite-based and ground-based instruments.
EXTEND	G/T Technical Connection: Read to be informed about visible and infrared images. University of Hawaii. *Virtually Hawaii. Visible and Infrared Tutorial.* Available: http://satftp.soest.hawaii.edu/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral.1.html ***Journal Write:*** 1. Why do satellites images have different colors? 2. How do we receive information from a satellite? Technical Connection: : Starting on page five, read about how and why satellite images are colored. University of Hawaii. *Virtually Hawaii. Visible and Infrared Tutorial.* Available: http://satftp.soest.hawaii.edu/space/hawaii/vfts/oahu/rem_sens_ex/rsex3.honolulu.html On page seven, visit the "Spectral Imager." Students make their own spectral image by assigning each band a color. University of Hawaii. *Introduction to Remote Sensing (Page 7): Select Your Own Color Combinations.* Available: http://satftp.soest.hawaii.edu/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral.4.html

	Have students share images and interpret the images based on the color combinations and the graphs that accompany the images. Analyze remote sensing images by completing the online activity NASA Observatorium. *Eyes in the Sky: A Remote Sensing Activity*. Available: http://observe.arc.nasa.gov/nasa/exhibits/eyes_sky/home.html Adaptive Strategy: Provide students with a calculator. Do a Think-aloud for analyzing the data for one of the images. INTEREST CENTER The website has many images with descriptions. Have students describe the bandwidths and images have helped researchers better understand changes in our environment. USGS. *Earth Shots.* Available: http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents NASA. *Visualization of Remote Sensing Data.* Available: http://rsd.gsfc.nasa.gov/rsd/
EVALUATE	***Journal Write:*** 1. Write a public service announcement or radio news article that describes the purpose and advantages of remote sensing. 2. Give examples of how the general public benefits from applications of remote sensing. Use information from your technical readings and online simulations.

Materials:

Resources:

NASA Observatorium. *Eyes in the Sky: A Remote Sensing Activity*. Available:

http://observe.arc.nasa.gov/nasa/exhibits/eyes_sky/home.html

University of Hawaii. *Introduction to Remote Radar Sensing.*
Available: http://satftp.soest.hawaii.edu/space/hawaii/vfts/kilauea/radar_ex/intro.html

University of Hawaii. *Introduction to Remote Sensing (Page 7): Select Your Own Color Combinations.*
Available:
http://satftp.soest.hawaii.edu/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral.4.html

University of Hawaii. *Shuttle Photographs.*
Available: http://mael.soest.hawaii.edu/space/hawaii/images/bigisle/island.shuttle.425x395.gif

NASA GSFC. *Stratospheric Ozone and Global Land Vegetation Modules*.
Available: http://see.gsfc.nasa.gov/edu/SEES/#who

University of Hawaii. *Virtually Hawaii.*
Available: http://mael.soest.hawaii.edu/space/hawaii/index.html

NASA. *Visualization of Remote Sensing Data.*
Available: http://rsd.gsfc.nasa.gov/rsd/

INTEREST CENTER

USGS. *Earth Shots.*
Available: http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents

NASA. *Visualization of Remote Sensing Data.*
Available: http://rsd.gsfc.nasa.gov/rsd/

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 4: REMOTE SENSING – ANALYSIS OF OZONE

Estimated Time: Two fifty-minute blocks

Indicator(s) Core learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.1 The student will identify meaningful, answerable scientific questions.

1.4.1 The student will organize data appropriately using techniques such as tables, graphs, and webs. (For graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title)

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

Indicator(s): Core Learning Goal 2:

2.1.2 The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth. Assessment limits (at least) –Tools (spectrometers, seismograph), Delivery systems (satellite-based, ground-based)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits (at least) –Atmospheric composition and structure (greenhouse gases, stratospheric ozone concentration and distribution, aerosols, temperature)

Student Outcome(s):

1. The student will be able to illustrate the concentration and distribution of stratospheric ozone by graphing and analyzing TOMS satellite data.
2. The student will be able to evaluate the effects of aerosols on the concentration of stratospheric ozone by reading a technical passage.

WHAT DOES THE RESEARCH SAY?

In studying the evolution of the earth system over geologic time, students develop a deeper understanding of the evidence, first introduced in grades 5-8, of earth's past and unravel the interconnected story of earth's dynamic crust, fluctuating climate, and evolving life forms. The students' studies develop the concept of the earth system existing in a state of dynamic equilibrium. They will discover that while certain properties of the earth system may fluctuate on short or long time scales, the earth system will generally stay within a certain narrow range for millions of years. This long-term stability can be understood through the working of planetary geochemical cycles and the feedback processes that help to maintain or modify those cycles. National Research Council, *National Science Education Standards* (1996).

Brief Description:

In this lesson, students analyze TOMS (Total Ozone Mapping Spectrometer) ozone concentration data to determine whether stratospheric ozone depletion is a global problem or merely a localized event. Students generate graphs using imagery created from the satellite Nimbus-7. They also examine ozone data collected in the Northern Hemisphere. Then, students interpret their graphs to determine the scope of ozone depletion. Furthermore, they delineate human-induced and natural causes of ozone depletion.

Background knowledge / teacher notes:

The following is ozone background information adapted from NASA's education office's ambassador investigation, "Ozone Over Your Head:"

Ozone is measured in a unit named for British physicist G.M.B. Dobson. The Dobson Unit (DU) is a measure of total ozone, which means that the tropospheric and stratospheric ozone layers are combined into one value.

One DU at sea level (at 0º C) would form a layer of ozone only 0.001 cm thick. If 100 DU of ozone were brought to the Earth's surface, it would form a layer only 1 mm thick. So while ozone is important, its volume in the atmosphere is naturally low. Dobson scale values typically fall between 100 & 600 DU. But you will see satellite data and images that show a variety of Dobson values.

Ozone Levels

In tropical areas (low latitudes), ozone levels are typically between 250 and 300 DU year round. However, in temperate regions, seasonal variations can produce large swings in ozone levels. For example, measurements in St. Petersburg, Russia, may be as high as 475 DU and as low as 300 DU. These variations are natural and occur even in the absence of man-made ozone depleting chemicals. In discussions of global environmental change "Ozone Depletion" refers to reductions in ozone below normal levels after accounting for seasonal cycles and other natural effects.

The term "ozone hole," which is used to describe the condition of stratospheric ozone, promotes a misconception and probably should not be used. There is no hole. Rather, there is an annual thinning or depletion of stratospheric ozone in the region over Antarctica between September and December. (Note: The term "ozone hole" is still widely used throughout NASA's websites.)

TOMS

The Total Ozone Mapping Spectrometer (TOMS) is an instrument placed in orbit around the Earth to measure ozone. The instrument has a 60 square kilometer field of view on Earth's surface. TOMS collects 35 measurements every eight seconds as it scans right to left producing approximately 200,000 ozone measurements daily. This covers the entire Earth except areas near the poles. TOMS measures atmospheric ozone by comparing incoming solar radiation with light reflected by the Earth. Therefore, it cannot take measurements at night, or during polar winter (when the sun remains below the horizon 24 hours per day). TOMS measures ozone by observing both incoming solar energy and "backscattered" ultraviolet (UV) radiation in six wavelengths. "Backscattered" radiation is solar radiation that has penetrated to Earth's lower atmosphere (the troposphere). It is scattered by air molecules and clouds back through the stratosphere to the satellite. In route, some of the UV is absorbed by ozone. TOMS measures "total column ozone;" the total amount of ozone in an imaginary column of atmosphere from Earth's surface to the satellite.

Note that TOMS was not in orbit during 1995 and the early part of 1996.

Additional background information about the TOMS program and about Nimbus-7 can be found at NASA GSFC. *Total Ozone Mapping Spectrometer.*
Available: http://jwocky.gsfc.nasa.gov/

Ozone shows up in lower concentrations in Antarctica for many complicated reasons. Some of these are related to the atmosphere being thinner at the poles, a lack of mountainous terrain, and well-developed wind patterns.
More background information about ozone and ozone depletion are available at U.S. Environmental Protection Agency. *Ozone Depletion.*
Available: http://www.epa.gov/ozone/science/
Additional images and animations may be found at NASA GSFC. *TOMS Multimedia Files.*
Available: http://jwocky.gsfc.nasa.gov/multi/multi.html

Lesson Description:

ENGAGE	Have students graph data from the Total Ozone Mapping Spectrometer (TOMS). Exploratorium. *Graphing Stratospheric Ozone.* Available: http://www.exploratorium.edu/learning_studio/ozone/graphing1.html What type of graph is most appropriate for the data? Materials: graph paper, ruler Teacher Note: the site contains basic instructions for graphing the data. Adaptive Strategy: Help students choose a location in South America or Antarctica to use as a data reference point for their graphs. Remind them to use the same location for each year that data is graphed. Provide a detailed map of South America if needed. Or students could analyze one of the ready-made graphs available at the site.

Discussion:

What does your graph indicate about the amount of stratospheric ozone in the Southern Hemisphere?

Read to be informed about ozone.

NASA Facts. *Ozone: What is it, and why do we care about it?*

Available: http://eospso.gsfc.nasa.gov/ftp_docs/Ozone.pdf

Or other similar text passages may be used.

Discussion:

1. Why is stratospheric ozone important to us?
2. Why are scientists investigating ozone in the stratosphere?

Technology Connection: View the Quick Time movie at NASA GSFC. *1998 Ozone Hole.*

Available: http://jwocky.gsfc.nasa.gov/multi/spol_98low.qt

Or

NOAA. Index of /products/stratosphere/tovsto/archive/anim. *TOVS Total Ozone Analysis Animation.*

Available:

http://www.cpc.ncep.noaa.gov/products/stratosphere/tovsto/archive/anim/9503.mpg

Move through the animations step-by-step to clearly see the development of the ozone hole.

Discussion:

1. What view of Earth is featured in this animation? *South Pole, or Antarctica.*
2. What phenomenon does the animation illustrate? Use evidence to support your answer. *Ozone "hole," ozone depletion, etc.*
3. How does this movie support or contradict the trend shown on your graph?

EXPLORE	Technology Connection: Have students analyze the ozone hole over time, by examining the graphs located at the following two websites. NASA GSFC. *Average area of ozone hole.* Available: http://jwocky.gsfc.nasa.gov/multi/oz_hole_area.jpg And NASA GSFC. *Antarctic ozone minimum.* Available: http://jwocky.gsfc.nasa.gov/multi/min_ozone.jpg Materials: drawing paper, colored pencils or markers Using the data from these two graphs, students create a color-coded diagram of the ozone layer for any year after 1993. Examples of color-coded diagrams, showing stratospheric ozone data for the years 1970 – 1993, are located at NASA GSFC. *BUV and TOMS Total Ozone.* Available: http://jwocky.gsfc.nasa.gov/multi/buv-toms.gif Adaptive Strategy: Provide students with a black line map of the world that clearly shows Antarctica. Allow them to do their illustration directly on the map. Aviso. *Antarctica and the Southern Ocean.* Available: www.jason.oceanobs.com/images/applications/antarctique.gif Or, a similar map may be used.
EXPLAIN	***Journal Write:*** 1. What change(s) do you see in the stratospheric ozone in Antarctica over time? 2. Does this trend extend to South America? Use evidence from the satellite data to support your answer.

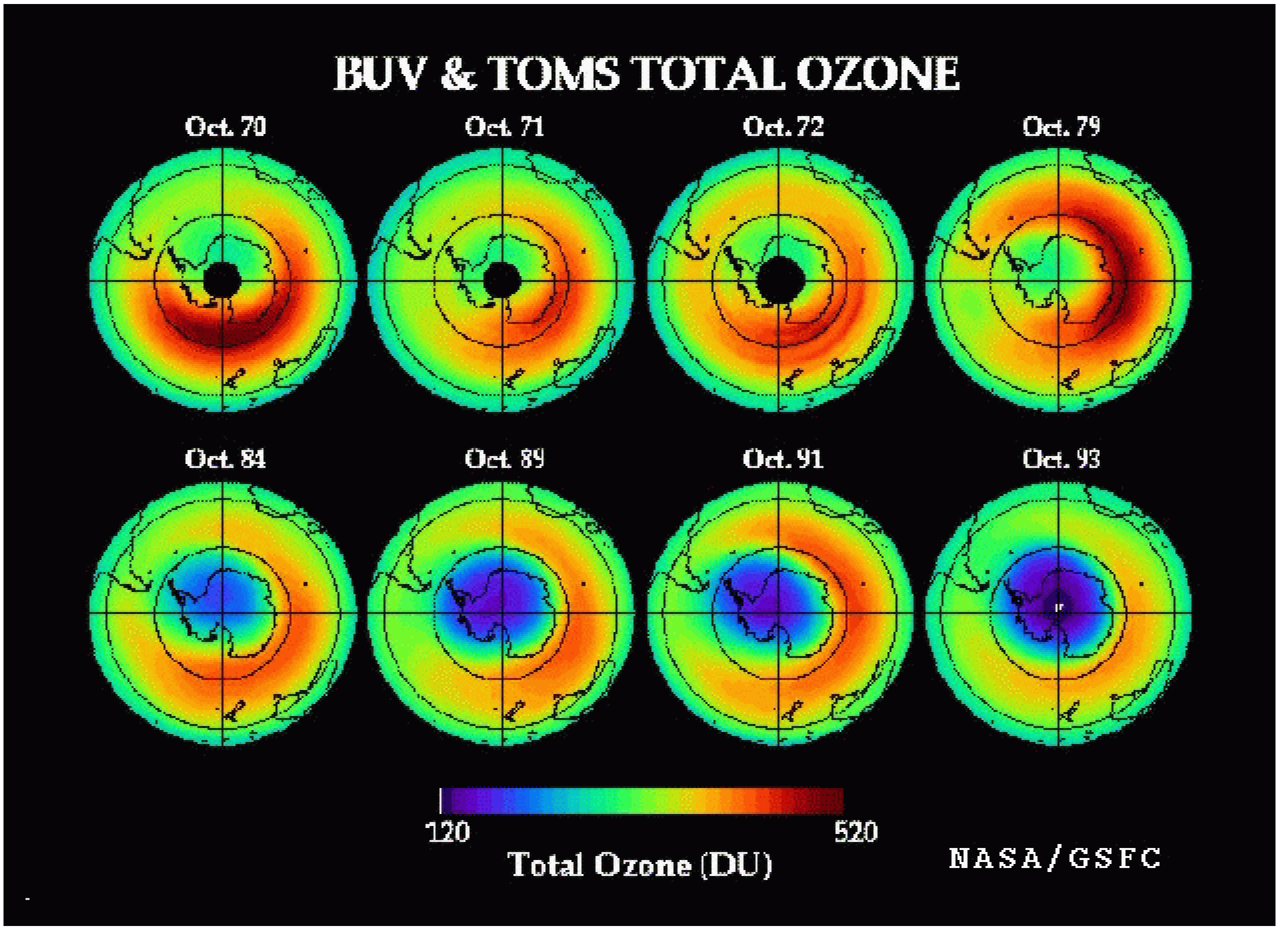
EXTEND	Technology Connection: Compare the ozone data for Antarctica and South America with data collected in the Arctic by visiting: NASA GSFC. *TOMS Total Ozone Monthly Averages.* Available: http://jwocky.gsfc.nasa.gov/multi/TOMSmarch79_98.gif G/T Connection: Compare the ozone data for Antarctica and South America with data collected in the Northern hemisphere by visiting NASA GSFC. *Ozone at Arosa, Switzerland since 1926.* Available: http://jwocky.gsfc.nasa.gov/multi/arosa2.gif ***Journal Write:*** 1. What change(s) do you see in the stratospheric ozone over the Arctic? Be sure to include evidence from TOMS data to support your answer. 2. Where is the largest area of ozone depletion? Read to be informed. What causes ozone depletion in the stratosphere? U.S. Environmental Protection Agency. *The Process of Ozone Depletion.* Available: http://www.epa.gov/ozone/science/process.html And U.S. Environmental Protection Agency. *Brief Questions and Answers on Ozone Depletion.* Available: http://www.epa.gov/docs/ozone/science/q_a.html ***Journal Write:*** 1. Why should we be concerned about ozone depletion? 2. Create a graphic organizer to illustrate the process of ozone depletion.

	3. What natural and human factors contribute to ozone depletion? 4. What is being done about ozone depletion? <u>Career Connection</u>: Investigate the careers of scientists who conduct ongoing investigations of Earth's atmosphere. NOAA. *Stratospheric Ozone Depletion.* Available: http://www.al.noaa.gov/WWWHD/pubdocs/StratO3.html <u>G/T Connection</u>: Describe the role of chlorine in ozone depletion? NAS. *Major and minor sources of stratospheric chlorine.* Available: http://www.nas.nasa.gov/About/Education/Ozone/depletion.html INTEREST CENTER Additional TOMS images are available by visiting NASA GSFC SeaWiFS. *Nimbus-7 Total Ozone Mapping Spectrometer (TOMS) Images*. Available: http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/OZONE.html
EVALUATE	***Journal Write***: 1. Using the TOMS data you have examined, describe how the concentration and distribution of stratospheric ozone has changed over time. 2. Is this cause for concern? 3. Evaluate the effects of aerosols on the concentration of ozone. What is being done to reverse the effect of aerosols? Use evidence from the reading to support your answer.

Earth/Space Systems Science
Unit II: The Atmosphere

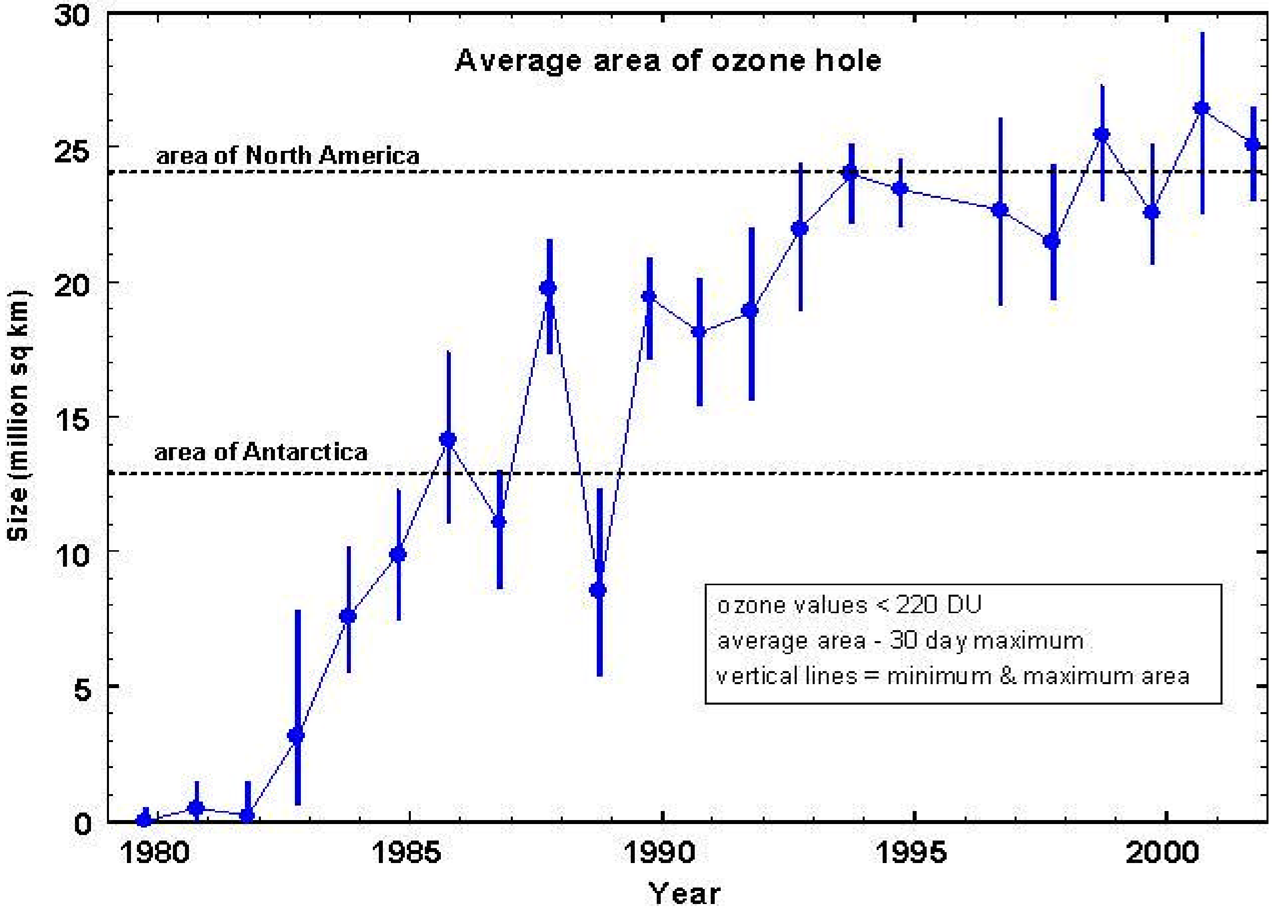
Materials:

- Graph paper
- Ruler
- Drawing paper
- Colored pencils or markers



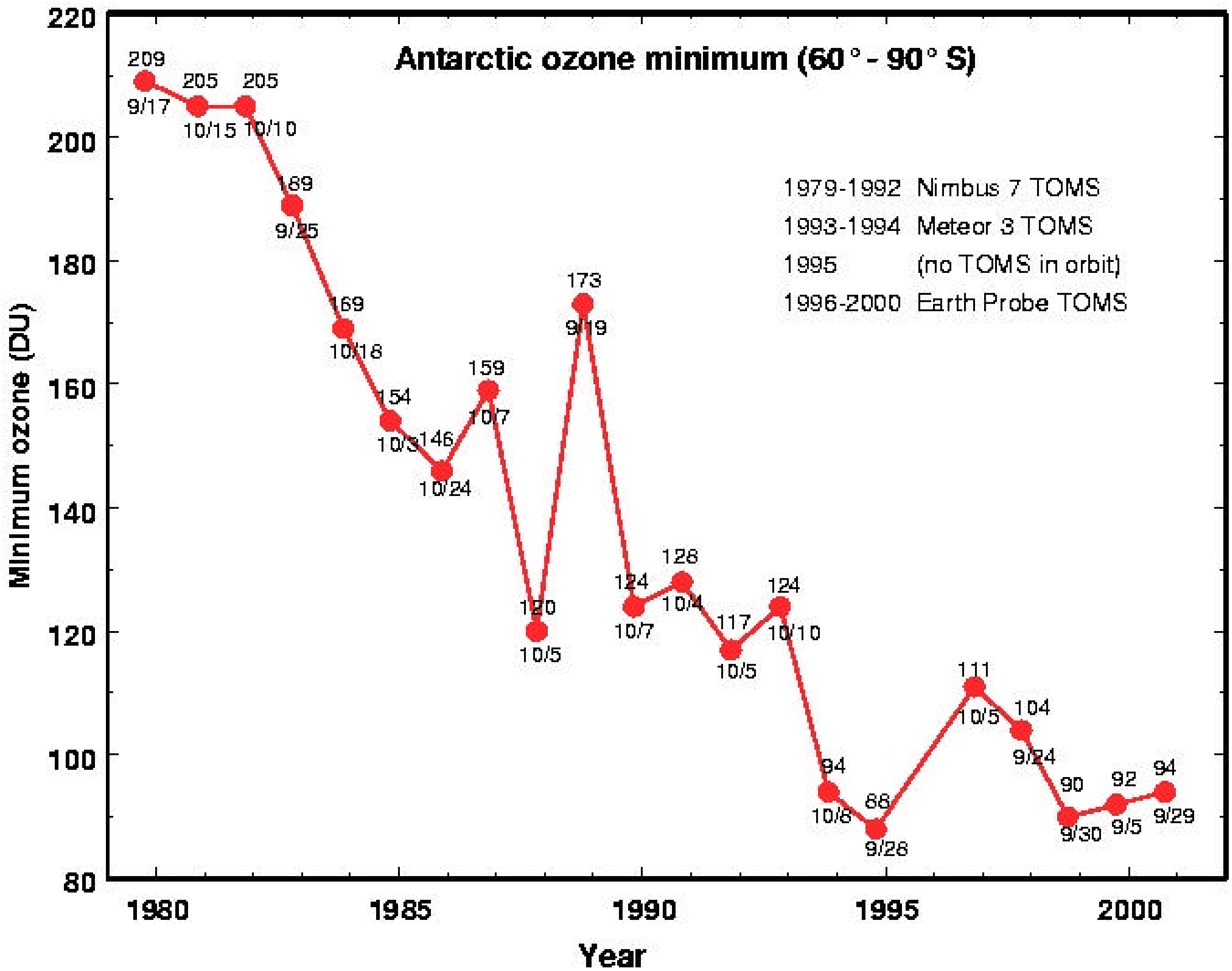
From NASA GSFC. *BUV and TOMS Total Ozone.*

Available: http://jwocky.gsfc.nasa.gov/multi/buv-toms.gif



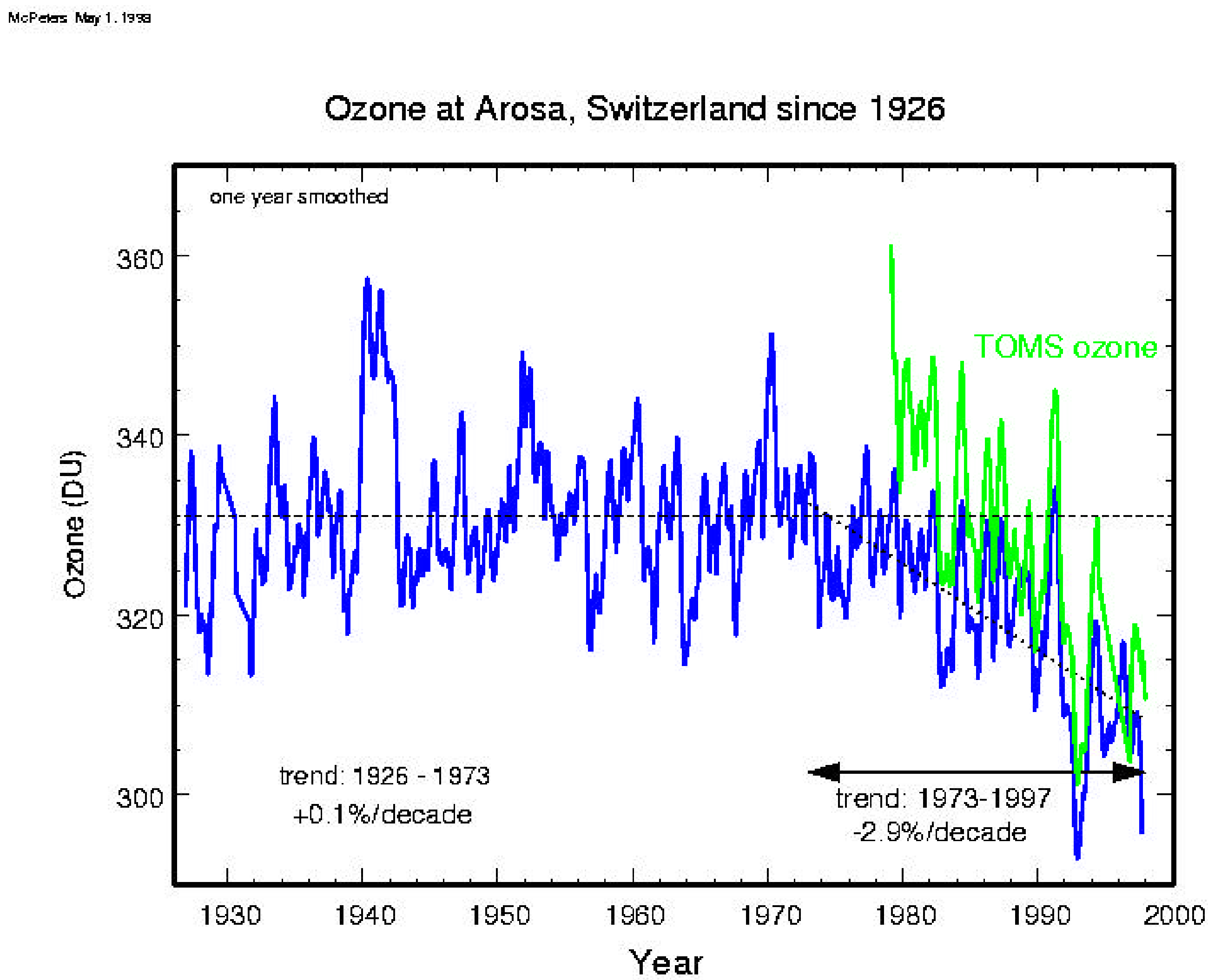
From NASA GSFC. *Average area of ozone hole.*

Available: http://jwocky.gsfc.nasa.gov/multi/oz_hole_area.jpg



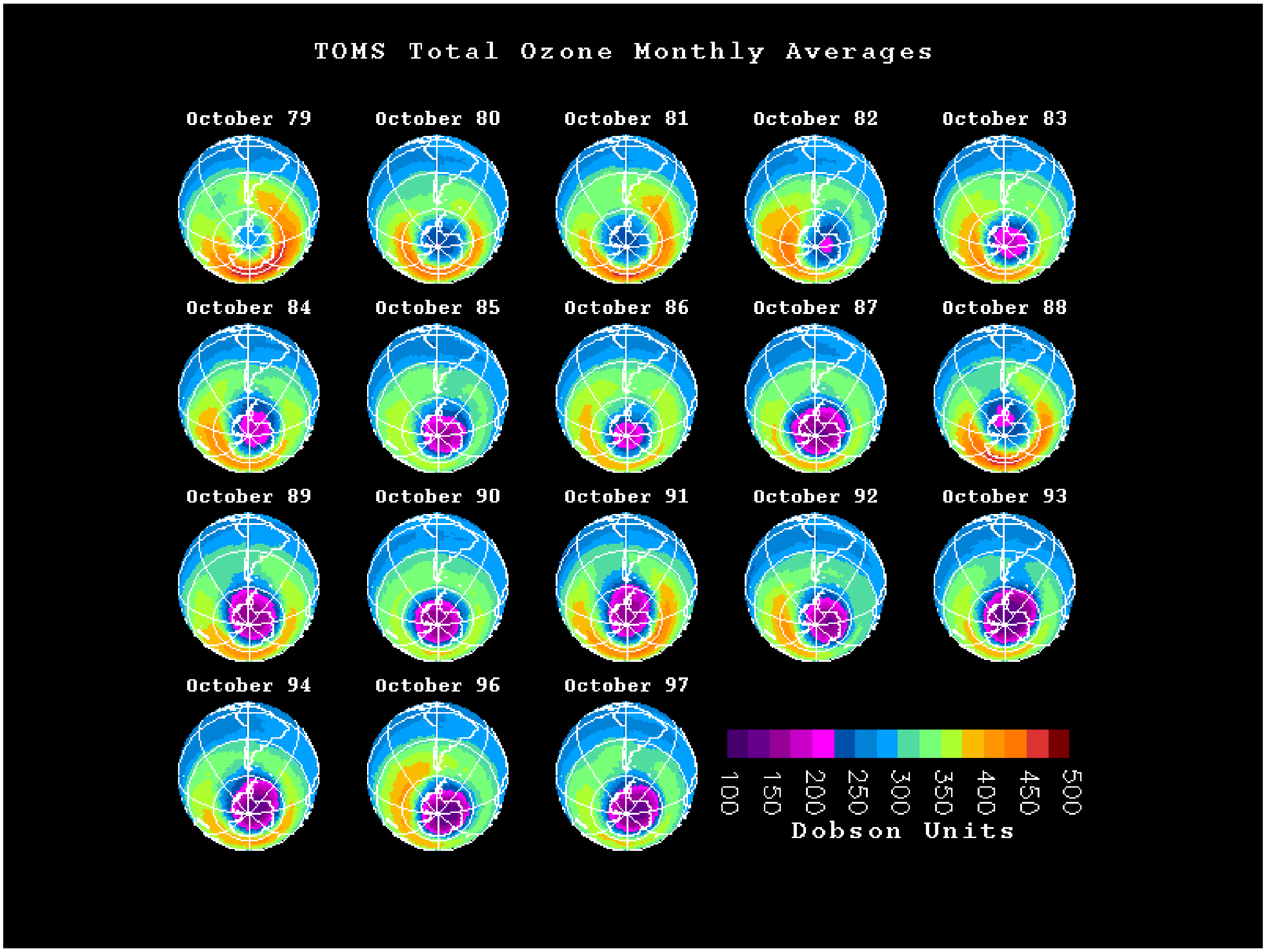
From NASA GSFC. *Antarctic ozone minimum.*

Available: http://jwocky.gsfc.nasa.gov/multi/min_ozone.jpg



NASA GSFC. *Ozone at Arosa, Switzerland since 1926.*

Available: http://jwocky.gsfc.nasa.gov/multi/arosa2.gif



NASA GSFC. *TOMS Total Ozone Monthly Averages.*

Available: http://jwocky.gsfc.nasa.gov/multi/TOMSmarch79_98.gif

Resources:

NASA GSFC. *1998 Ozone Hole.*

Available: http://jwocky.gsfc.nasa.gov/multi/spol_98low.qt

NASA GSFC. *Antarctic ozone minimum.*

Available: http://jwocky.gsfc.nasa.gov/multi/min_ozone.jpg

Aviso. *Antarctica and the Southern Ocean.*

Available: www.jason.oceanobs.com/images/applications/antarctique.gif

NASA GSFC. *Average area of ozone hole.*

Available: http://jwocky.gsfc.nasa.gov/multi/oz_hole_area.jpg

U.S. Environmental Protection Agency. *Brief Questions and Answers on Ozone Depletion.*

Available: http://www.epa.gov/docs/ozone/science/q_a.html

NASA GSFC. *BUV and TOMS Total Ozone.*

Available: http://jwocky.gsfc.nasa.gov/multi/buv-toms.gif

Exploratorium. *Graphing Stratospheric Ozone.*

Available: http://www.exploratorium.edu/learning_studio/ozone/graphing1.html

NASA NAS. *Major and minor sources of stratospheric chlorine.*

Available: http://www.nas.nasa.gov/About/Education/Ozone/depletion.html

NASA GSFC. *Ozone at Arosa, Switzerland since 1926.*

Available: http://jwocky.gsfc.nasa.gov/multi/arosa2.gif

U.S. Environmental Protection Agency. *Ozone Depletion.*

Available: http://www.epa.gov/ozone/science/

NASA Facts. *Ozone: What is it, and why do we care about it?*
Available: http://eospso.gsfc.nasa.gov/ftp_docs/Ozone.pdf

U.S. Environmental Protection Agency. *The Process of Ozone Depletion.*
Available: http://www.epa.gov/ozone/science/process.html

NOAA. *Stratospheric Ozone Depletion.*
Available: http://www.al.noaa.gov/WWWHD/pubdocs/StratO3.html

NASA GSFC. *Total Ozone Mapping Spectrometer*.
Available: http://jwocky.gsfc.nasa.gov/

NASA GSFC. *TOMS Multimedia Files.*
Available: http://jwocky.gsfc.nasa.gov/multi/multi.html

NASA GSFC. *TOMS Total Ozone Monthly Averages.*
Available: http://jwocky.gsfc.nasa.gov/multi/TOMSmarch79_98.gif

NOAA. Index of /products/stratosphere/tovsto/archive/anim. *TOVS Total Ozone Analysis Animation.*
Available: http://www.cpc.ncep.noaa.gov/products/stratosphere/tovsto/archive/anim/9503.mpg

INTEREST CENTER

NASA GSFC SeaWiFS. *Nimbus-7 Total Ozone Mapping Spectrometer (TOMS) Images*.
Available: http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/OZONE.html

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 5: ALBEDO

Estimated Time: Two fifty-minute blocks

Indicator(s) Core Learning Goal 1:

1.2.2 The student will pose meaningful, answerable scientific questions.

1.2.3 The student will formulate a working hypothesis.

1.2.4 The student will test a working hypothesis.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.4.6 The student will describe trends revealed by data.

Indicator(s): Core Learning Goal 2

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) -Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits (at least) – Cloud cover (amount, type, albedo)

Student Outcome(s):

The student will be able to explain albedo and describe its effect on heat absorption by conducting laboratory investigations.

WHAT DOES THE RESEARCH SAY?

Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

National Research Council, *National Science Education Standards* (1996).

Earth/Space Systems Science
Unit II: The Atmosphere

Brief Description:

In this lesson, students use a light probe, and various shades of gray paper to investigate the relationship between surface colors and albedo. Using this knowledge, students explore the effect of albedo on heat absorption. This may be a CBL or computer based lab.

Background knowledge / teacher notes:

Albedo is the amount of light energy reflected by an object. It is usually expressed as a decimal fraction of incoming radiation or as a percentage of incoming radiation. Albedo is calculated using the following formula: Reflected radiation /Incident radiation x 100% = Albedo.

Reflected radiation is measured by pointing the light probe at a surface and reading the value displayed on the CBL screen.

Incident (incoming) radiation is measured by pointing the light probe at the light source (inside the light source is the room lights; outside it's the sun.).

Usually, lighter objects have a higher albedo than darker objects. In general, a surface with low albedo absorbs more energy than it reflects. The amount of energy absorbed is often measured as a rise in temperature.

Teacher note: When using the light probe outside, the ambient light level is higher than the unit's ability to measure, making it cumbersome to do measurements outside as extensions. Easy fix: Put an aperture mask over the light sensor, thus cutting down on the light that reaches the photoelectric cell under bright sun conditions. Wrap the aluminum foil over the end of the probe, thus covering the sensor window. Punch a small hole in the foil, directly over the middle of the sensor window, using a sharp pencil point. This hole allowed just enough light into the sensor, so that the probe could now be used outside in bright sunlight.

Teacher note: Photocopy, cut out, and mount on a stiff backing paper, the gray scale cards in Resources.

Credit: Adapted with permission from Montgomery County Public Schools Honors Earth Science Curriculum Guide. The original lesson is titled "Measuring Surface Albedo" and was developed and written by Leslie Rogers.

Lesson Description:

ENGAGE	Teacher Demonstration: Using a light probe attached to a CBL, demonstrate how to measure the amount of light reflected from an object. 1. Choose students that have on dark colored clothes or light colored clothes. 2. Point the light probe at them and ask if they are warm or cold. 3. Read the data from the CBL to the class and say whether or not you believe them. Discussion 1. What am I measuring? *The amount of light reflected.* 2. Introduce the term "albedo" and explain how to calculate albedo. *Albedo is the reflectivity of an object. It is usually expressed as a decimal fraction of incoming radiation or as a percentage of incoming radiation.* *Albedo is calculated using the following formula:* *Reflected radiation /Incident radiation x 100% = Albedo* *Reflected radiation is measured by pointing the light probe at a surface and reading the value displayed on the CBL screen.* *Incident (incoming) radiation is measured by pointing the CBL at the light source (indoors it's the room lights, outside it's the sun).*
EXPLORE	Working in small groups, students design a laboratory investigation to determine the relationship between the type of surface and the amount of albedo. Materials: CBL or computer, light probes, gray scale cards <u>Adaptive Strategy</u>: Provide students with an experiment design sheet. Do a think-aloud to model how to write procedures. ***Journal Write:***

	1. Write a hypothesis about how the color of a surface affects its albedo. 2. Write laboratory procedures. 3. Design a data table to record the amount of albedo. After receiving the teacher's permission, conduct the experiment.
EXPLAIN	***Journal Write:*** 1. Examine the data. Describe the trend. 2. What is the effect of surface color on the amount of albedo? Use data from your investigation to support your answer. 3. Explain why skiers wear sunglasses and sunscreen. Discussion: Show students a picture of Earth with the ice cap. Space Pix. *Earth.* Available: http://www.spacepix.net/earth/earth_apollo_17.htm Based on what you know about albedo, which parts of Earth have the highest albedo? *Polar ice caps, deserts…* Predict how differences in albedo might affect climate.
EXTEND	Give each pair of students the "Average Albedo of Common Surfaces" table. ***Journal Write:*** 1. Examine the albedo data. Predict how albedo affects heat absorption. 2. Using the following materials: light, white paper, black paper, thermometer, meter stick, design a laboratory investigation to test your hypothesis. 3. Make a data table to record temperatures. 4. After receiving permission from the teacher, conduct the investigation.

	<u>Adaptive Strategy</u>: Provide students with an experiment design sheet. Sample laboratory procedures may be found at Atmospheric Sciences 101. *Radiation and Albedo.* Available: http://www.atmos.washington.edu/2002Q1/101/demos/demo2.htm <u>G/T Connection:</u> Examine other colors of paper or the effect of texture on heat absorption. For example, compare construction paper to copier paper. ***Journal Write:*** Use the data from your investigation to describe how albedo affects heat absorption. Discussion: 1. Why do we wear dark colored clothes in the winter and light colored clothes in the summertime? Use evidence from your laboratory investigations to support your answer. 2. How do differences in albedo affect climate? *Areas with high albedo have low heat absorption and have a cooler climate.*
EVALUATE	***Journal Write:*** 1. Define albedo. 2. How does albedo affect heat absorption? Use evidence from your laboratory investigation to support your answer. 3. How can albedo affect climate?

Materials:

- CBLs or computers
- Light probes
- Gray scale cards

- Experimental design sheet
- Lamps
- Meter sticks
- Thermometers
- White paper
- Black paper
- Colored paper and colored construction paper

Average Albedo of Common Surfaces

Types of Surfaces	Albedo as a Decimal	Albedo as a Percentage
Asphalt	≤ .10	≤ 10%
Water (overhead Sun)	.03-.05	3-5%
Forest	.05-.10	5%-10%
Soil	.11-.20	11-20%
Grass	.20-.25	20-25%
Sand	.20-.30	20-30%
Evergreen vegetation	.31-.40	31-40%
Developed terrain: concrete, buildings etc.	.51-.71	51-70%
Water varies depending upon position of sun. (sun near horizon)	.50-.80	50-80%
Thick cloud	.70-.80	70-80%
Fresh snow/ice	.70-.85	70-85%

Experimental Design

TITLE OF THE EXPERIMENT: ________________________________

QUESTION OR PROBLEM: ________________________

____

HYPOTHESIS: ____

____

MATERIALS: ____________________________________

____

PROCEDURE

____

____

____

____

____

____

DATA

Think about how you are going to collect your data. Design a table to record your data.

Results

1. Do you see a trend in the data?
2. What do your results mean?

____

____

____

CONCLUSION:

1. What did you learn from this experiment?
2. Does your data support your hypothesis?
3. What evidence do you have to support your conclusion?

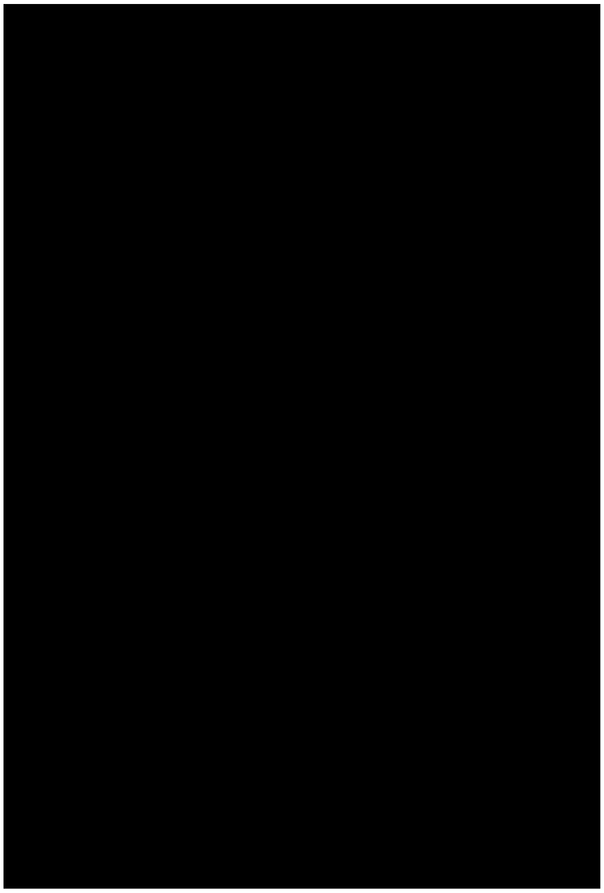
____

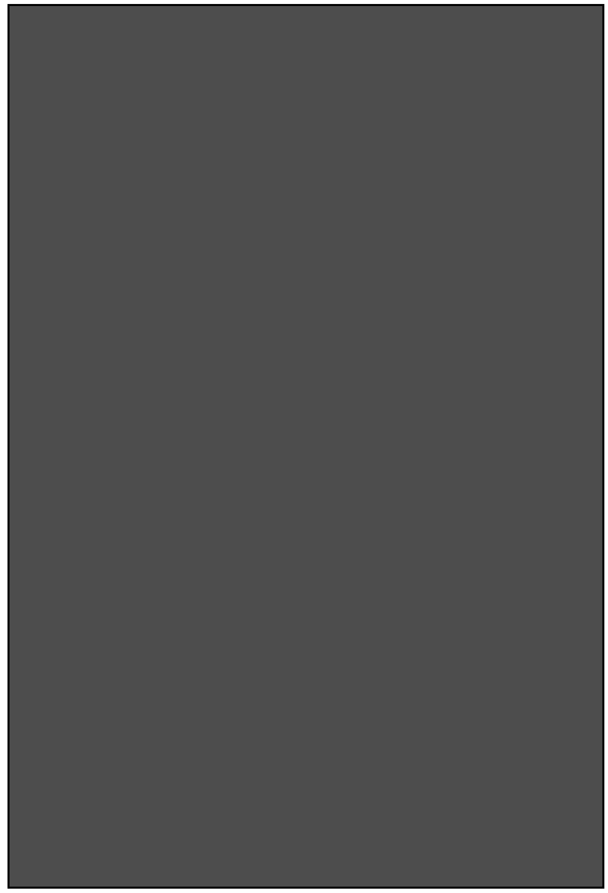
____

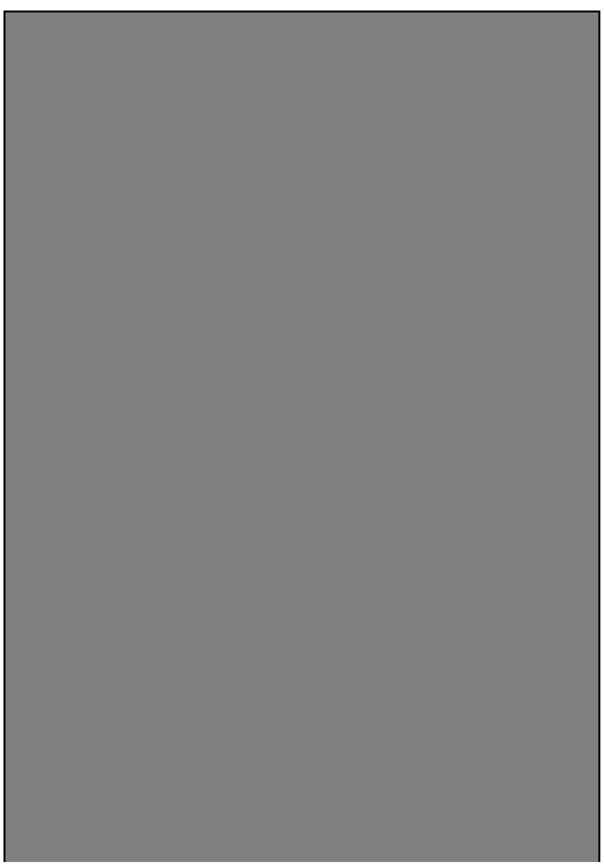
____

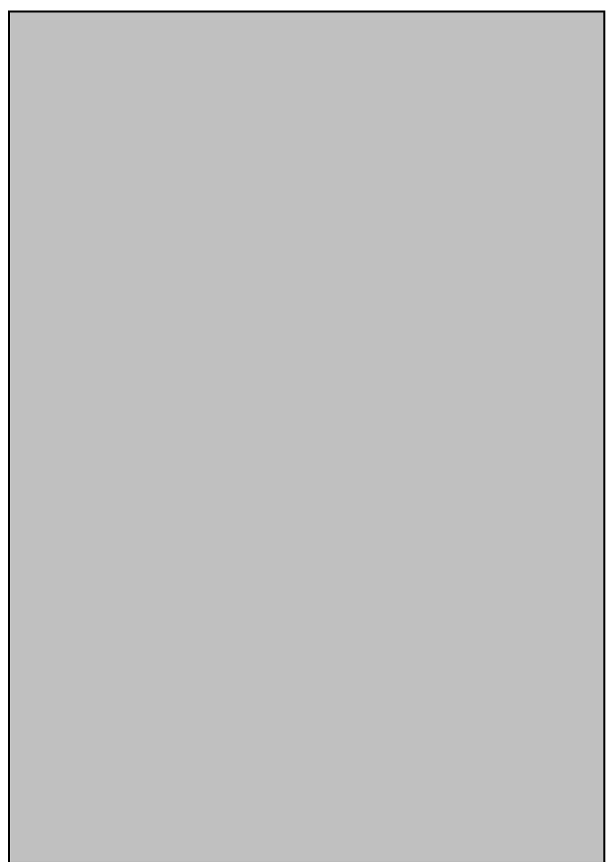
____

Earth/Space Systems Science
Unit II: The Atmosphere









Resources:

Space Pix. *Earth.*

Available: http://www.spacepix.net/earth/earth_apollo_17.htm

Atmospheric Sciences 101. *Radiation and Albedo.*

Available: http://www.atmos.washington.edu/2002Q1/101/demos/demo2.htm

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 6: CLOUDS

Estimated Time: One fifty-minute block

Indicator(s) Core learning Goal 1:

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.2 The student will explain scientific concepts and processes through drawing, writing, and/or oral communication.

1.5.6 The student will read a technical selection and interpret it appropriately.

1.5.7 The student will use, explain, and/or construct various classification systems.

Indicator(s): Core Learning Goal 2:

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter. Assessment limits (at least) – Cloud cover (amount, type, albedo)

Student Instructional Outcomes:

1. The student will be able to compare types of clouds by analyzing their characteristics.
2. The student will be able to explain the impact of cloud cover on weather by reading a technical selection.

WHAT DOES THE RESEARCH SAY?

During the high school years, students continue studying the earth system introduced in grades 5-8. At grades 9-12, students focus on matter, energy, crustal dynamics, cycles, geochemical processes, and the expanded time scales necessary to understand events in the earth system. Driven by sunlight and earth's internal heat, a variety of cycles connect and continually circulate energy and material through the components of the earth system. Together, these cycles establish the structure of the earth system and regulate earth's climate. In grades 9-12, students review the water cycle as a carrier of material, and deepen their understanding of this key cycle to see that it is also an important agent for energy transfer.

National Research Council, *National Science Education Standards* (1996).

Brief Description:

In this lesson, students investigate the conditions that cause clouds to form. They create a graphic organizer comparing common types of clouds. Students examine the relationship between cloud cover and weather and begin to explore the influence of clouds on climatic change.

Background knowledge / teacher notes:

Clouds can occur in any mixture of gases provided the following conditions apply:

· The temperature of the mixture of gases (air) is below the temperature of condensation of one of the gases (water vapor).

· The relative concentration of water vapor is at or above its saturation point, i.e., the relative humidity of the air is 100%.

· It is very helpful if tiny particles (dust, pollen, salt, etc.) are present. These serve as condensation nuclei.

Whenever these conditions are present, tiny droplets of liquid water will form around the condensation nuclei. When this happens at ground level, the result is fog or mist. At higher altitudes, we call it cloud. If the temperature is below the freezing temperature of water, tiny ice crystals form instead of liquid water. This is why high altitude clouds are made of ice crystals.

Clouds occur on any planet (or moon) that has an atmosphere of mixed gases as long as the above conditions apply. The condensing liquid does not have to be water; on other planets it can be carbon dioxide, ammonia, methane, or even sulfuric acid.

Lesson Description:

ENGAGE	Show students an image of Earth that shows cloud cover. Use a poster or project one of the many photographs of Earth taken from space that can be found online NASA Earth Observing System. *Wonderglobe*. Available: http://eospso.gsfc.nasa.gov/eos_homepage/dp/wonderglobe/wonderglobe_1152x870.jpg Discussion: 1. What is a cloud? 2. How do they form? How Do Clouds Form? Materials: clear 2-liter soda bottle with cap, matches, water Directions: 1. Rinse bottle and leave a few drops of water in the bottle. 2. Swirl the water around to moisten all sides of the bottle. 3. Drop a lit match into the bottle. 4. Place the cap tightly on the bottle. 5. Squeeze the bottle gently and then release. 6. Repeat steps 1 through 4 if necessary. Modified from Union College. *Cloud Formation – "A Cloud in a Bottle."* Available: http://www.union.edu/PUBLIC/GEODEPT/hollocher/sciencelabs/Labs/BBML1/BBML1.htm. <u>Adaptive Strategy</u>: Perform this simulation as a demonstration.

	Journal Write: 1. What conditions are necessary for clouds to form? *Moisture, cool temperatures, particulates* 2. How do clouds form? *As water vapor rises into the atmosphere, it cools and condenses around dust particles, releasing latent heat into the atmosphere. As the temperature drops, the water vapor condenses and clouds form.* Adaptive Strategy: Read to be informed about how clouds form. Create and complete a graphic organizer on cloud formation. Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Atmosphere: Moisture in the Atmosphere." pp. 285 – 286. Or, a similar text passage may be used or, visit the following website: AngliaCampus. *How Clouds Form.* Available: http://www.angliacampus.com/public/pri/geog/rivers/page04.htm
EXPLORE	View different types of clouds. Sandia National Laboratories. *Clouds.* Available: http://www.sandia.gov/ciim/ISA/1clouds.html#form PSC Meteorology Program. *Cloud Boutique.* Available: http://vortex.plymouth.edu/clouds.html Discussion: 1. How do clouds differ? *Altitude or height, appearance, composition.* 2. Why are there different types of clouds?
EXPLAIN	Read to be informed about the types of clouds and complete a graphic organizer. Glencoe (2002) Earth Science: Geology, the Environment, and the Universe, "Types of Clouds." pp. 287-290. Or, other similar text passage or websites may be used.

<table>
<tr><td></td><td>GOES.NOAA. Geostationary Satellite Server.
Available: http://www.goes.noaa.gov/
University of Washington. Houze's Cloud Atlas.
Available: www.atmos.washington.edu/gcg/Atlas\

Journal Write:
Create a graphic organizer comparing appearance or form, height or altitude, composition of clouds. There are three basic forms cirrus, cumulus, and stratus. Cirrus: high, white, thin, Cumulus: large puffy clouds, Stratus: sheets, no distinct clouds</td></tr>
<tr><td>EXTEND</td><td>Read to be informed about clouds, weather, and climate. Create and complete a graphic organizer about clouds, weather, and our climate.
USA today. Weather. Clouds Aren't Really a Blanket on Cold Nights.
Available: http://www.usatoday.com/weather/wcldwarm.htm
Environmental Technology Laboratory. Clouds and Climate.
Available: http://www.etl.noaa.gov/eo/notes/clouds_and_climate.html
Or other similar text passages.
Journal Write:
1. How does cloud cover impact our daily temperatures? Help regulate temperatures by keeping heat in, but also can reflect solar radiation.
2. How do clouds influence our climate?
3. What tools do scientists use to study clouds and our climate?

How do meteorologist use clouds to forecast weather?
Weather Warehouse. Meteorology Primer. A Primer in Meteorology.
Available: http://www.weatherwarehouse.com/primer.htm</td></tr>
</table>

	INTEREST CENTER: Clouds can occur on any planet with an atmosphere. NASA. *Astronomy Picture of the Day, April 17, 2001.* Available: http://antwrp.gsfc.nasa.gov/apod/ap010417.html NASA. *Astronomy Picture of the Day, September 20, 1997.* Available: http://antwrp.gsfc.nasa.gov/apod/ap970920.html NASA JPL. *Cassini/Galileo Images of Jupiter's System.* Available: http://www.jpl.nasa.gov/pictures/jupiter/ Malin Space Science Systems. *Mars Global Surveyor, Mars Orbiter Camera* Available: http://www.msss.com/mars_images/moc/9_19_98_endSPO2_rel/9_19_98_npole_rel/index.html NASA GSFC. *Mars Pathfinder Images.* Available: http://nssdc.gsfc.nasa.gov/planetary/marspath_images.html NASA GSFC. *NSSDC Photo Gallery - Venus.* Available: http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-venus.html#clouds SEDS. *Venus.* Available: http://seds.lpl.arizona.edu/nineplanets/nineplanets/venus.html

EVALUATE	***Journal Write:*** 1. Compare the major types of clouds. Be sure to describe their height or altitude, appearance or form, and composition. 2. How do clouds influence our daily weather? Use evidence to support your answer.

Materials:

- Clear 2-liter soda bottle with cap
- Matches
- Water

Resources:

Weather Warehouse. Meteorology Primer. *A Primer in Meteorology.*
Available: http://www.weatherwarehouse.com/primer.htm

Union College. *Cloud Formation – "A Cloud in a Bottle."*
Available:
http://www.union.edu/PUBLIC/GEODEPT/hollocher/sciencelabs/Labs/BBML1/BBML1.htm.

Sandia National Laboratories. *Clouds.*
Available: http://www.sandia.gov/ciim/ISA/1clouds.html#form

USA today. Weather. *Clouds Aren't Really a Blanket on Cold Nights.*
Available: http://www.usatoday.com/weather/wcldwarm.htm

Environmental Technology Laboratory. *Clouds and Climate.*
Available: http://www.etl.noaa.gov/eo/notes/clouds_and_climate.html

PSC Meteorology Program. *Cloud Boutique.*
Available: http://vortex.plymouth.edu/clouds.html

GOES.NOAA. *Geostationary Satellite Server.*
Available: http://www.goes.noaa.gov/

Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Atmosphere: Moisture in the Atmosphere." pp. 285 – 286.

Glencoe (2002) Earth Science: Geology, the Environment, and the Universe, "Types of Clouds." pp. 287-290.

University of Washington. *Houze's Cloud Atlas.*
Available: www.atmos.washington.edu/gcg/Atlas\

AngliaCampus. *How Clouds Form.*
Available: http://www.angliacampus.com/public/pri/geog/rivers/page04.htm

NASA Earth Observing System. *Wonderglobe*.
Available:
http://eospso.gsfc.nasa.gov/eos_homepage/dp/wonderglobe/wonderglobe_1152x870.jpg

INTEREST CENTER

NASA. *Astronomy Picture of the Day, April 17, 2001*.
Available: http://antwrp.gsfc.nasa.gov/apod/ap010417.html

NASA. *Astronomy Picture of the Day, September 20, 1997.*
Available: http://antwrp.gsfc.nasa.gov/apod/ap970920.html

NASA JPL. *Cassini/Galileo Images of Jupiter's System.*
Available: http://www.jpl.nasa.gov/pictures/jupiter/

Malin Space Science Systems. *Mars Global Surveyor, Mars Orbiter Camera.*
Available:
http://www.msss.com/mars_images/moc/9_19_98_endSPO2_rel/9_19_98_npole_rel/index.html

NASA GSFC. *Mars Pathfinder Images.*
Available: http://nssdc.gsfc.nasa.gov/planetary/marspath_images.html

NASA GSFC. *NSSDC Photo Gallery - Venus.*
Available: http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-venus.html#clouds

SEDS. *Venus.*
Available: http://seds.lpl.arizona.edu/nineplanets/nineplanets/venus.html

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 7: FACTORS THAT INFLUENCE EARTH'S ENERGY BUDGET

Estimated Time: Three fifty-minute blocks

Indicator(s) Core learning Goal 1:

1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.1.3 The student will critique arguments that are based on faulty, misleading data or on the incomplete use of numbers.

1.1.4 The student will recognize data that are biased.

1.1.5 The student will explain factors that produce biased data (including incomplete data, using data inappropriately, conflicts of interest, etc.).

1.4.5 The student will check graphs to determine that they do not misrepresent results.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.6 The student will read a technical selection and interpret it appropriately.

1.5.9 The student will communicate conclusions derived through a synthesis of ideas.

1.7.1 The student will apply the skills, processes, and concepts of biology, chemistry, physics, and earth science to societal issues.

Indicator(s): Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems.
Assessment limits (at least) -Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

2.3.2 The student will explain how global conditions are affected when natural and human-induced change alter the transfer of energy and matter.
Assessment limits (at least) –Atmospheric composition and structure (greenhouse gases, stratospheric ozone concentration and distribution, aerosols, temperature)
Pollutants (particulates, tropospheric ozone concentration and distribution, acid rain)

Cloud cover (amount, type, albedo)

Student Outcome(s):

The student will be able to interpret Earth's energy budget by analyzing the effects of cloud cover, greenhouse gases, and particulates.

WHAT DOES THE RESEARCH SAY?

Energy is a mysterious concept, even though its various forms can be precisely defined and measured. At the simplest level, children can think of energy as something needed to make things go, run, or happen. But they have difficulty distinguishing energy needs from other needs—plants need water to live and grow; cars need water, oil, and tires; people need sleep, etc. People in general are likely to think of energy as a substance, with flow and conservation analogous to that of matter. That is not correct, but for most people it can be an acceptable analogy. Although learning about energy does not make it much less mysterious, it is worth trying to understand because a wide variety of scientific explanations are difficult to follow without some knowledge of the concept of energy.

Energy is a major exception to the principle that students should understand ideas before being given labels for them. Children benefit from talking about energy before they are able to define it. Ideas about energy that students encounter outside of school—for example, getting "quick energy" from a candy bar or turning off a light so as not to "waste energy"— may be imprecise but are reasonably consistent with ideas about energy that we want students to learn.

Three energy-related ideas may be more important than the idea of energy itself. One is energy transformation. All physical events involve transferring energy or changing one form of energy into another—radiant to electrical, chemical to mechanical, and so on. A second idea is the conservation of energy. Whenever energy is reduced in one place, it is increased somewhere else by exactly the same amount. A third idea is that whenever there is a transformation of energy, some of it is likely to go into heat, which spreads around and is therefore not available for use. AAAS. *Benchmarks for Science Literacy.* (1993).

Earth/Space Systems Science
Unit II: The Atmosphere

Brief Description:

In this lesson, students analyze incoming and outgoing radiation. They examine whether the Earth's temperature remains constant, and what this means in terms of Conservation of Energy. Students explore the effects of specific variables within Earth's atmosphere on Earth's energy budget – variables such as cloud cover, particulates, and greenhouse gases.

Background knowledge / teacher notes:

Almost all of the energy for atmospheric processes is radiant energy from the Sun. Most of this radiant energy is in the form of visible, short wave, and ultraviolet radiation. Most of the ultraviolet radiation is absorbed by ozone high in the atmosphere. About 30% of the total incoming solar radiation is reflected back to space by clouds and the Earth's surface. Some incoming radiation can also be stopped by particulates in the atmosphere and is either reflected or absorbed. Twenty-five percent is absorbed by the atmosphere and re-radiated back into space and 45% is absorbed by the surface of the land and water. This energy is used to evaporate water, carry out photosynthesis, and move winds, currents, and waves. Greenhouse gases trap some of the energy before it is radiated back towards space. This causes the temperature of Earth and its lower atmosphere to be higher than one might expect. Short wave radiation that is not absorbed by the ozone layer penetrates the surface of the Earth. The energy is then re-radiated back as energy of a longer wavelength (infrared), leading to a warming of Earth's surface and the lower atmosphere.

Clouds, particulates, and greenhouse gases are components of the atmosphere that affect Earth's energy budget. Variations in these components drive changes in Earth's energy budget.

Thick clouds in the lower atmosphere, with their high albedo, reflect a high percentage of the incoming (incident) solar radiation. Thus, they have a cooling effect on the Earth's surface and the lower atmosphere. Thin, high altitude clouds reflect far less incident radiation, allowing most of it to pass through to heat the Earth's surface. However, these same thin high clouds reflect much of the infrared radiation that is re-radiated from the surface, thus helping trap it.

Earth's cloud cover is highly variable, both locally and globally. Their effect on Earth's energy budget is also variable.

Particulates (microscopic solid particles suspended in the atmosphere) reflect, scatter, and absorb solar radiation. A high concentration of particulates in the atmosphere – such as these produced by volcanic eruptions – can substantially reduce the amount of radiation reaching Earth's surface, and reduce its temperature. Major eruptions can have almost immediate profound impacts on worldwide climate: The recent eruption of Mt. Pinatubo reduces Earth's average surface temperature for several years. The eruption of Mt. Tambora in Indonesia in April of 1815 sent enormous amounts of particulates into the atmosphere, which strongly affected global weather; the following year has been called "The Year Without a Summer." The more recent eruption of Mt. Pinatubo in the Philippines measurably lowered the average temperature of Earth's surface. A brief discussion of these effects can be found at SSES/CIMSS/AOS. *Volcanoes and Climate.*
Available: http://itg1.meteor.wisc.edu/wxwise/museum/a5/a5volcan.html

Greenhouse gases (especially carbon dioxide) receive regular attention in the press and media to the extent that some students assume that all such gases are strictly the product of human activity. This lesson can help students understand that, while human activity is evidently affecting the picture, greenhouse gases and their effect on Earth's energy budget are vital natural phenomena. Basically, all greenhouse gases are transparent to sunlight in the visible spectrum. Light from the Sun can travel unhindered through these gases, to strike the surface of the Earth, where it is absorbed to heat the surface. But these gases are opaque to wavelengths in the infrared range; in other words, they trap heat radiation. So infrared radiation from the warmed surface, which may otherwise escape into space, is trapped in the atmosphere. Since energy loss is hindered, the overall temperature of the Earth's surface and atmosphere is increased. If it were not for this greenhouse effect, the overall temperature of the Earth would be much lower than it is – low enough that most water on Earth would be frozen.

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson Description:

ENGAGE	Discussion: 1. How many of you have jobs? Receive an allowance? Have credit cards? 2. We read about people who have thousands of dollars in credit card debt. Why are so many people in debt? 3. What's the solution? *Budget* 4. What is a budget? *A balance between what's coming in (income) and what's going out (expenses).* Discussion: Display a globe, or illustration of the whole Earth. 1. Earth also has a budget. What is the "money" that earth uses? *Energy* 2. Where does this energy come from? *Sun or solar radiation*
EXPLORE	Read to be informed about what happens to solar radiation once it reaches Earth. Glencoe McGraw-Hill. (2001). <u>Glencoe Earth Science: Geology, the Environment and the Universe.</u> pp. 275-276. Or other similar text passages. ***Journal Write:*** What happens to solar radiation once it reaches Earth? *Some solar radiation is reflected back into space from clouds, particles in the atmosphere, or from the land or ocean surface. Ultraviolet forms of radiation are absorbed by the ozone layer. Visible light and some ultraviolet and infrared radiation may reach Earth's surface. Sunlight absorbed by the land and oceans warms the planet's surface.* Read about the Greenhouse Effect. LiftOff Exploration. *The Greenhouse Effect.*

	Available: http://liftoff.msfc.nasa.gov/academy/space/greenhouse.html Or other similar text passages. ***Journal Write:*** How does solar radiation warm the planet? *Earth's atmosphere acts like a greenhouse, warming our planet in much the same way that an ordinary greenhouse warms the air inside its glass walls. Like glass, the gases in the atmosphere let in light yet prevent heat from escaping. This natural warming of the planet is called the greenhouse effect.*
EXPLAIN	Discuss in small groups 1. What happens to solar radiation once it reaches Earth? 2. How does solar radiation warm the planet?
EXTEND	Provide students with a diagram of Earth's energy budget. NASA. *Earth's Energy Budget Image.* Available: http://asd-www.larc.nasa.gov/erbe/components2.gif Or NWS. Southern Region Headquarters. NOAA. *Energy Budget Image.* Available: http://www.srh.noaa.gov/MAF/SatTutor/ch3_4.htm Or other similar diagrams. Discussion: 1. What factors affect the temperature of Earth? 2. What things cause the temperature to rise? To fall? List responses on the board or overhead.

	Discuss whether the factors are income (temperature rises) or expense (temperature falls) Each group of students investigates one of the environmental factors that affect Earth's Energy Budget: clouds, particulates, and greenhouse gases. Adaptive Strategy: Provide the students with graphic organizers, skeleton outlines, or a list of questions to be answered with information they discover. Pre-reading focus questions: 1. As you read the articles about your environmental topic, think about whether or not the conclusions being presented are biased. 2. What are some clues to look for to determine if the data is biased or misleading? ***Journal Write:*** 1. Create and complete a graphic organizer about your environmental topic. 2. How does your environmental factor affect Earth's Energy Budget? Use data or evidence from the reading for support. 3. Evaluate whether some of the data or conclusions you are using may be biased? Cite evidence to support your conclusion. Teacher Note: Below is a list of suggested websites for the students to use. They are arranged by topic. Effect of Clouds: NASA Langley Research Center - Multimedia Repository. *Ceres Cloud Effects.* Available: http://lisar.larc.nasa.gov/MOVIES/SMALL/LV-1997-

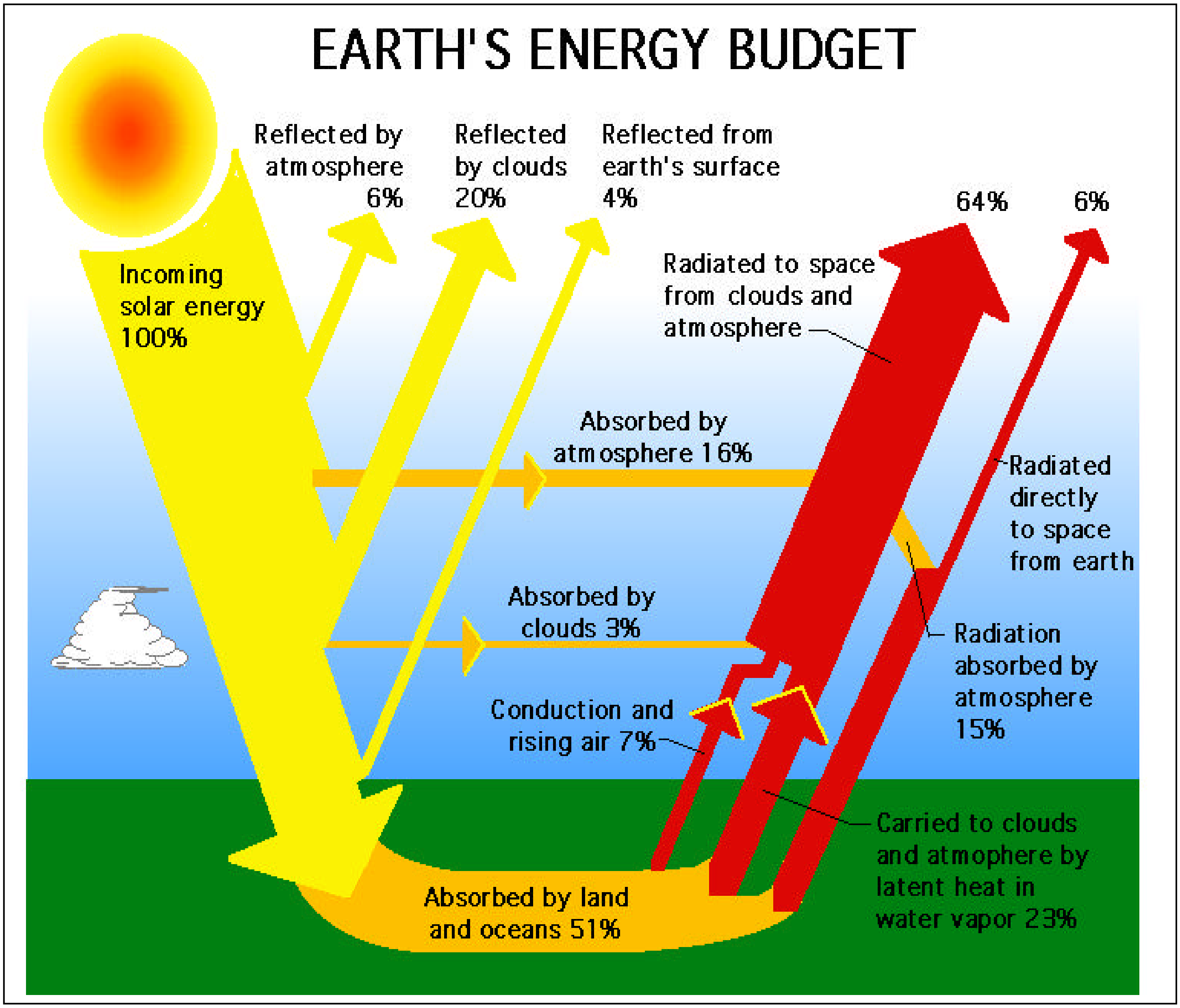
	00003.mov This site shows an animation of how clouds affect the energy budget on the earth. NASA Facts Online. *The Earth Radiation Budget Experiment (ERBE).* Available: http://oea.larc.nasa.gov/PAIS/ERBE.html This site describes NASA's ERBE mission and the relevance of the data collected to determine the earth's energy budget. NASA. TRMM. *Tropical Rainfall Measuring Mission.* Available: http://trmm.gsfc.nasa.gov/overview_dir/ceres.html Adaptive Strategy: Read about the effect of clouds before viewing the animation on *Ceres Cloud Effects.* SSES/CIMSS/AOS. *Planet Emission Temperature Climate Model.* Available: http://itg1.meteor.wisc.edu/wxwise/museum/a5/a5run1.html This site has an interactive activity that examines the effects albedo on temperature. Effects of particulates: I. Rokityansky. *Extended Spectrum of Lithosphere-Atmosphere Treats.* Available: http://216.239.51.100/search?q=cache:BHuzrPmopaUC:www.agu.org/meetings/cc02babstracts/Rokityansky.pdf+%2Bvolcano+eruption+dust+climate&hl=en&ie=UTF-8 Nature. Science Update. *Smoke Clouds Weather.* Available: http://www.nature.com/nsu/020218/020218-6.html SSES/CIMSS/AOS. *Volcanoes and Climate.*

	Available: http://itg1.meteor.wisc.edu/wxwise/museum/a5/a5volcan.html Exploring the Environment. *Volcanoes and Climate.* Available: http://www.cotf.edu/ete/modules/volcanoes/vclimate.html Or other similar text passages. Effect of Greenhouse Gases: FACSNET. Issue. *Global Climate Change: What It Is Not.* Available: http://www.facsnet.org/issues/specials/gcc/basic/effect.php3 This site has a text overview of the solar energy budget and brief discussion of the effect of greenhouses gases. Climate Change. Canada. *The Greenhouse Effect.* Available: http://adaptation.nrcan.gc.ca/posters/articles/ac_03_en.asp?Region=ac&Language=en Prepare a short presentation for the class describing the effects of your environmental factor on Earth's Energy Budget. After each group presents their information to the class, encourage the class to discuss the influence of the environmental factors. ***Journal Write:*** Write a brief summary describing the influence of each environmental factor on the energy budget. Adaptive Strategy: Help students create a graphic organizer to complete during the presentations. Discussion: 1. Should we be concerned about human influence on the energy budget?

	2. What are some possible solutions to counteract humans' influence? G/T Connection: Assuming that only a disc of the sun is reaching the Earth's surface at one time, we can use the proportion $(ro/r)^2$ by the inverse square law. Demonstrate the inverse square law and discover how the wavelength is a function of the energy released by an emitter. Discover Earth. *Earth's Energy Budget or Can You Spare a Sun? Activity 3. Solar Luminosity.* Available: http://www.strategies.org/LESSON8.html INTEREST CENTER Venus provides a fascinating comparison to Earth. Its extremely high surface temperatures (the highest in the Solar System) are accounted for by what is called a "runaway greenhouse effect". Windows to the Universe. *The Atmosphere of Venus.* Available: http://www.windows.ucar.edu/tour/link=/venus/atmosphere.html University of Tennessee. Astronomy 101. The Solar System. *A Runaway Greenhouse Effect.* Available: http://csep10.phys.utk.edu/astr161/lect/venus/greenhouse.html
EVALUATE	***Journal Write:*** For each of these changes listed below, predict what effect the change will have on Earth's Energy Budget. Support your answer using evidence from your reading and class discussion. · The average amount of clouds in Earth's atmosphere increases. · The Sun increases its output. · A volcano erupts and sends huge amounts of dust into Earth's atmosphere. · The concentration of carbon dioxide in the atmosphere increases.

Materials:

- Large sheets of newsprint
- Markers
- Overhead transparency sheets
- Compact fluorescent light source
- Incandescent light source
- Flashlight
- Graph paper - 2 sheets (1 cm x 1 cm grid)
- Meter stick
- Spectroscope



From NASA. *Earth's Energy Budget Image.*

Available: http://asd-www.larc.nasa.gov/erbe/components2.gif

G/T Connection: **Solar Luminosity**

Outcome: Students will be able to determine the spectra of light sources with different intensities, and relate the spectra to the energies of each.

Background:

One aspect of the energy balance--solar luminosity--is a function of the energy given off by the Sun and the Earth-Sun distance. To calculate the energy given off by the Sun, you must look at the electromagnetic spectrum. Waves that have a shorter wavelength, such as x-rays, give off higher amounts of energy. Waves that have a longer wavelength, such as infrared rays, give off lower amounts of energy. The Sun is a black body--meaning it gives off energy at all wavelengths all the time. Using the Stefan-Boltzmann law, we can determine how much energy is given off by the Sun. The formula for this is:

$$E = \sigma T^4$$

E is the amount of energy released in W/m^2

T is the temperature of the Sun in Kelvins

σ is the Stefan-Boltzmann constant of $5.67 \times 10^{-8}\ W/m^2/K^4$.

Assuming that only a disc of the sun is reaching the Earth's surface at one time, we can use the proportion $(ro/r)^2$ by the inverse square law. In this exercise, you attempt to demonstrate the inverse square law and discover how the wavelength is a function of the energy released by an emitter.

Materials**:** compact fluorescent light source, flashlight, graph paper - 2 sheets (1 cm x 1 cm grid) incandescent light source, meter stick, spectroscope

Procedure:

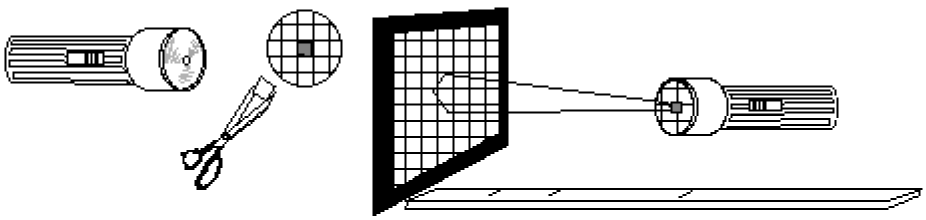
1. Turn on the incandescent light source.
2. View the light source through the spectroscope.
3. Record your observations of the wavelengths of this light source and the relative heat given off by the light bulb.
4. Turn off the incandescent light source, and turn on the compact fluorescent light source.
5. Record your observations of the wavelengths of this light source and the relative heat given off of the light bulb.
6. Turn off the compact fluorescent light source.

Answer conclusion questions 1-3 in your journal.

7. Cut a circle from graph paper that will cover the surface of the flashlight.
8. Cut out only one (1 cm X 1 cm) square closest to the center of the circle.
9. Attach the circle to the flashlight.
10. Attach an uncut piece of graph paper to the black construction paper.
11. Position the paper at one end of the meter stick and the flashlight rim at a distance of 5 centimeters from the edge of the ruler.
12. Turn the flashlight on and count the number of squares illuminated on the graph paper. Record your results.
13. Now move the rim of the flashlight to a distance of 10 centimeters from the edge of the meter stick.
14. Count and record the number of grid squares illuminated.

15. Finally, move the rim of the flashlight to a distance of 20 centimeters away from the edge of the meter stick.
16. Count and record the number of grid squares illuminated.
17. Graph the results as a function of distance between the flashlight and the graph paper and the number of squares illuminated.

Answer conclusion questions 4-7 in your journal.



Conclusion Questions:

1. What wavelengths of light did the incandescent light source give off? What wavelengths did the compact fluorescent light give off?
2. Which was hotter, the incandescent light or the compact fluorescent light?
3. What conclusion can you make between the amount of energy (heat) given off and the wavelength of the light?
4. How many squares on the graph were illuminated when the distance was 5 centimeters? 10? 20?
5. Reference the graph distance and illuminated squares. How many squares would be lit if the distance were 15 centimeters? 30 centimeters?
6. Extrapolate the graph to determine the number of lit squares if the distance were increased to 40 centimeters. Is this what you expected?
7. Based on your data, formulate a relationship between the distance of the objects and the amount of light received.

Earth/Space Systems Science
Unit II: The Atmosphere

Discover Earth. *Earth's Energy Budget or Can You Spare a Sun? Activity 3: Solar Luminosity*

Credit: Tom Gates, Oklahoma State University, NASA Ames Research Center Office Dale E. Peters, Urbana High School, Ijamsville, MD, Jeanne Seeley, Randolph High School, Randolph, NJ.

Available: http://www.strategies.org/LESSON8.html

Resources:

NASA Langley Research Center - Multimedia Repository. *Ceres Cloud Effects.*
Available: http://lisar.larc.nasa.gov/MOVIES/SMALL/LV-1997-00003.mov

Discover Earth. *Earth's Energy Budget or Can You Spare a Sun? Activity 3: Solar Luminosity*
Credit: Tom Gates, Oklahoma State University, NASA Ames Research Center Office
Dale E. Peters, Urbana High School, Ijamsville, MD, Jeanne Seeley, Randolph High School, Randolph, NJ.
Available: http://www.strategies.org/LESSON8.html

NASA. *Earth's Energy Budget Image.*
Available: http://asd-www.larc.nasa.gov/erbe/components2.gif

NASA Facts Online. *The Earth Radiation Budget Experiment (ERBE).*
Available: http://oea.larc.nasa.gov/PAIS/ERBE.html

NWS. Southern Region Headquarters. NOAA. *Energy Budget Image.*
Available: http://www.srh.noaa.gov/MAF/SatTutor/ch3_4.htm

I. Rokityansky. *Extended Spectrum of Lithosphere-Atmosphere Treats.*
Available:
http://216.239.51.100/search?q=cache:BHuzrPmopaUC:www.agu.org/meetings/cc02babstracts/Rokityansky.pdf+%2Bvolcano+eruption+dust+climate&hl=en&ie=UTF-8

Glencoe McGraw-Hill. (2001). Glencoe Earth Science: Geology, the Environment and the Universe. pp. 275-276.

FACSNET. Issue. *Global Climate Change: What It Is Not.*
Available: http://www.facsnet.org/issues/specials/gcc/basic/effect.php3

Climate Change. Canada. *The Greenhouse Effect.*

Available:

http://adaptation.nrcan.gc.ca/posters/articles/ac_03_en.asp?Region=ac&Language=en

LiftOff Exploration. *The Greenhouse Effect.*

Available: http://liftoff.msfc.nasa.gov/academy/space/greenhouse.html

SSES/CIMSS/AOS. *Planet Emission Temperature Climate Model.*

Available: http://itg1.meteor.wisc.edu/wxwise/museum/a5/a5run1.html

Nature. Science Update. *Smoke Clouds Weather*.

Available: http://www.nature.com/nsu/020218/020218-6.html

NASA. TRMM. *Tropical Rainfall Measuring Mission.*

Available: http://trmm.gsfc.nasa.gov/overview_dir/ceres.html

SSES/CIMSS/AOS. *Volcanoes and Climate.*

Available: http://itg1.meteor.wisc.edu/wxwise/museum/a5/a5volcan.html

Exploring the Environment. *Volcanoes and Climate.*

Available: http://www.cotf.edu/ete/modules/volcanoes/vclimate.html

INTEREST CENTER

Windows to the Universe. *The Atmosphere of Venus.*

Available: http://www.windows.ucar.edu/tour/link=/venus/atmosphere.html

University of Tennessee. Astronomy 101. The Solar System. *A Runaway Greenhouse Effect.*

Available: http://csep10.phys.utk.edu/astr161/lect/venus/greenhouse.html

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 8: THE CORIOLIS EFFECT

Estimated Time: One fifty-minute block

Indicator(s) Core learning Goal 1:

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.5.4 The student will use tables, graphs, and displays to support arguments and claims in both written and oral communications.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, field of view, etc.).

1.5.6 The student will read a technical selection and interpret it appropriately.

1.5.8 The student will describe similarities and differences when explaining concepts and/or principles.

Indicator(s): Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) - Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

Student Outcome(s):

The student will be able to describe how the Coriolis effect influences atmospheric circulation by analyzing the results of a laboratory investigation.

WHAT DOES THE RESEARCH SAY?

Global climate is determined by energy transfer from the sun at and near the earth's surface. Dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans influence this energy transfer. National Research Council, *National Science Education Standards* (1996).

Earth/Space Systems Science
Unit II: The Atmosphere

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.
AAAS, *Benchmarks for Science Literacy* (1993).

Brief Description:
In this lesson, students perform a laboratory investigation that simulates the Coriolis effect. By analyzing and interpreting the results of this investigation, they determine how Earth's rotation, and consequently the Coriolis effect, influences the circulation of the atmosphere.

Background knowledge / teacher notes:
Because Earth rotates, wind and water do not circulate in a straight line, but are deflected. In the Northern Hemisphere, Earth's rotation causes air cells to revolve in a clockwise or anticyclonic direction. This movement is counterclockwise, or cyclonic, in the Southern Hemisphere. Known as the Coriolis effect, this phenomenon is responsible for east-west movements of surface winds.
Often water going down a sink is given as an example of the Coriolis effect, but really isn't. Because the Earth's angular velocity is so small (360 degrees per day, or about 2 x 10-5 radians per second), the Coriolis effect is insignificant over small distances. In a sink, speeds and time scales are much smaller than hours and miles necessary for the Coriolis effect.
What causes the water to spin down the drain? Things like leftover spin from filling the sink (even when the water looks still, it's rotating slowly for a long time after it seems to stop), irregularities in the construction of the basin, convection currents if the water is warmer or colder than the basin, and so forth, can affect the direction water goes down the sink. Any one of these factors is usually more than enough to overwhelm the small contribution of the Coriolis effect in your kitchen sink or bathtub.

Water in the sink doesn't go far enough to trigger a noticeable north/south deflection. Most often, it simply spirals down the sink the way it went into the sink.

What things are likely to be affected by the Coriolis effect in a large way?

- Large weather systems feature masses of air and moisture that travel hundreds of miles and can have wind speeds reaching over a hundred miles an hour in the worst storms.
- Quickly moving objects in the sky covering hundreds of miles such as an airplane. All pilots need to have familiarity with the Coriolis effect, since airplanes can reach speeds much higher than even the fastest hurricane winds. Over the course of a several hour trip, an airplane could be deflected by a significant amount if the pilot didn't compensate for the Coriolis effect.
- Artillery shells and missiles fired over the horizon can miss by hundreds of meters if the Coriolis effect is not taken into account.

Modified from The Ohio University. David J. Van Domelen. *Getting Around the Coriolis Force.* Available: http://www.physics.ohio-state.edu/~dvandom/Edu/newcor.html

Lesson Description:

ENGAGE	Provide each group of students with a globe. Directions: 1. Locate the Northern hemisphere. 2. Demonstrate Earth's rotation by spinning the globe. 3. Observe the North Pole. Is the rotation clockwise or counterclockwise? *counterclockwise* 4. While the globe is still spinning, flip it over so that the South Pole is on top. 5. Observe the South Pole. Is the rotation clockwise or counterclockwise? *clockwise* <u>Adaptive Strategy</u>: Help students decide which way to spin the globe. In which direction does the sun rise? *east The sun rises earlier in the east and later in the west.* Compared to Maryland, when does the sun rise in California? *3 hours later*

	Demonstrate sunrise by shining a light on the globe. Rotate the globe toward the light demonstrating why sunrise is later in the west. Show students the turntable they use in the Coriolis Lab. Discussion: 1. This turntable represents Earth. If I want to study objects in the Northern Hemisphere, which way should I rotate the table? *Counterclockwise* 2. If I want to study objects in the Southern Hemisphere, which way should I rotate the table? *clockwise*
EXPLORE	Working in small groups, have students explore the Coriolis effect. The Coriolis Effect Materials: Coriolis Kit Directions: 1. Lift the sheet on the turntable. This will clear it so no marks are visible. 2. Take the launcher and position it so that the open end is toward the center of the platform. 3. Place the steel ball in the launcher - close to the front. HOLD ON TO THE BALL. 4. Without rotating the turntable (Earth), release the ball. ***Journal Write:*** 5. Draw the path the ball followed in the circle below. USE AN ARROW TO INDICATE DIRECTION 6. What conclusion can you draw about the path objects would follow on earth's surface if Earth were stationary? 7. Place the ball in the launcher all the way around the "C" shape. HOLD THE BALL. 8. Simulate movement in the Northern hemisphere by slowly rotating the turntable counterclockwise (spin it to the right). Continue

	rotating slowly and release the ball. ***Journal Write:*** 9. In the circle below, draw the path of the ball on the turntable. 10. What difference do you observe between the two lines in A and B? 11. Why does this apparent deflection (curving) occur? 12. Predict how moving objects in the Northern hemisphere would be affected. Use evidence to support your answer. Place the ball in the launcher all the way around the "C" shape. HOLD ON TO THE BALL. 13. Simulate movement in the Southern hemisphere by slowly rotating the turntable in a clockwise direction (spin it to the LEFT). Continue rotating and release the ball. ***Journal Write:*** 14. Draw the path the ball followed in the circle below. 15. How does this path compare with the one in circle B? 16. Predict how moving objects in the Southern hemisphere would be affected. Use evidence to support your answer. 17. Continue rotating the table in either direction and observe not the line on the tracing paper, but the actual direction and path of the ball. 18. Repeat until you can answer the following question. ***Journal Write:*** 19. Did the ball actually curve as it rolled across the turntable? (Hint: compare circles A and B) Use evidence to support your answer. Adaptive Strategy: Chunk the directions and questions. Model how to position the launcher and release the ball. This activity may be done as a demonstration. Teacher Note: If you do not have the Coriolis platform, a turntable

	may be substituted. Materials: blank paper, phonograph, "lazy Susan," or other turntable Directions: 1. Place a blank piece of paper on the turntable. 2. Draw a line from the center of the table out to the edge. 3. Turn on the turntable. 4. Draw a line from the center of the paper while it is turning.
EXPLAIN	As a class, discuss the results of the Coriolis effect laboratory investigation. Do a Think-Pair-Share Predict how a moving object, such a global wind, would be affected by the earth's rotation.
EXTEND	Read to be informed about the Coriolis force/effect. Danish Wind Industry. Wind Power. *The Coriolis Force*. Available: http://www.windpower.dk/tour/wres/coriolis.htm Adaptive Strategy: NASA. The NASA Science Files. *The Atmosphere.* Available: http://whyfiles.larc.nasa.gov/text/kids/Problem_Board/problems/light/sim3.html Or other similar text passages. Technology Connection: View a simulation of the Coriolis effect. PSU. *Coriolis Ball.* Available: http://www.essc.psu.edu/~pavloski/meteo3/l10/coriolisball.mov ***Journal Write:***

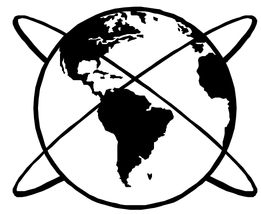
	1. Describe the Coriolis effect. 2. How does the Coriolis effect affect moving objects in the Northern Hemisphere? Southern Hemisphere? G/T/Technical Connection: View a global wind circulation simulation. NASA JPL. *Gwind.* Available: http://winds.jpl.nasa.gov/movies/Gwind3_320_cine2x.mov Or NOVA Online Adventure. *Global Wind Patterns.* Available: http://www.pbs.org/wgbh/nova/elnino/now/mapping13llarge.html Teacher Note: In order to detect the pattern, show the simulation several times. The pattern is mostly easily detected in the North Atlantic and Indian Oceans. ***Journal Write:*** 1. Observe the winds carefully and describe the general wind patterns in the Northern Hemisphere. 2. Describe the relationship between locations on earth and the strength of the Coriolis effect. Use evidence from the simulation and laboratory investigation to support your answer. *Although all locations on earth rotate in 24 hours, the land at the equator is moving much faster than the land at the poles. "At the equator a point travels at a velocity of 1041 miles per hour (1676 kilometers per hour), while a point at 80ºN latitude has a velocity of only 181 miles per hour (292 kilometers per hour)." Thus the Coriolis effect is strongest at the poles and weakest at the equator.* Fayette State University. Ronald Johnston. *Project NOVA. Module 3. Lesson 3 Coriolis Effect.* Available: http://www.uncfsu.edu/msec/nova/timmod3d.htm
EVALUATE	***Journal Write:***

	1. What is the Coriolis effect? 2. How does it influence atmospheric circulation?

Materials:

- Blank paper
- Phonograph, “Lazy Susan” or other turntable
- Coriolis Kit

The Coriolis Effect



Materials: Coriolis Kit

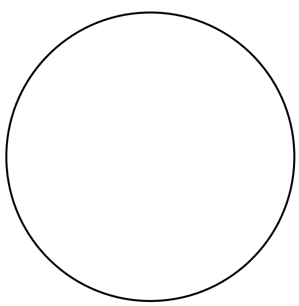
Directions:

1. Lift the sheet on the turntable. This will clear it so no marks are visible.
2. Take the launcher and position it so that the open end is toward the center of the platform.
3. Place the steel ball in the launcher - close to the front. HOLD ON TO THE BALL.
4. Without rotating the turntable (Earth), release the ball.

Journal Write:

5. Draw the path the ball followed in the circle below. USE AN ARROW TO INDICATE DIRECTION

A



6. What conclusion can you draw about the path objects would follow on earth's surface if Earth were stationary?

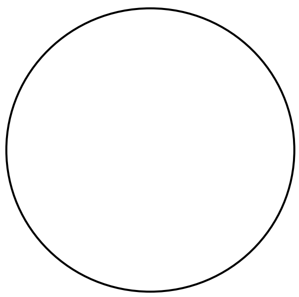
7. Place the ball in the launcher all the way around the "C" shape. HOLD THE BALL.

8. Simulate movement in the Northern hemisphere by slowly rotating the turntable counterclockwise (spin it to the right). Continue rotating slowly and release the ball.

Journal Write:

9. In the circle below, draw the path of the ball on the turntable.

B



10. What difference do you observe between the two lines in A and B?

11. Why does this apparent deflection (curving) occur?

12. Predict how moving objects in the Northern hemisphere would be affected. Use evidence to support your answer.

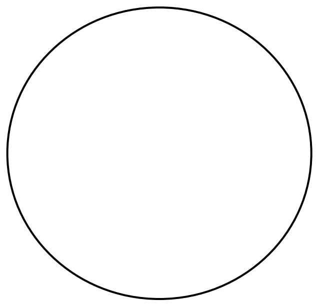
13. Place the ball in the launcher all the way around the "C" shape. HOLD ON TO THE BALL.

14. Simulate movement in the southern hemisphere by slowly rotating the turntable in a clockwise direction (spin it to the LEFT). Continue rotating and release the ball.

Journal Write:

15. Draw the path the ball followed in the circle below.

C



16. How does this path compare with the one in circle B?

17. Predict how moving objects in the Southern hemisphere would be affected. Use evidence to support your answer.

18. Continue rotating the table in either direction and observe not the line on the tracing paper, but the actual direction and path of the ball.

19. Repeat until you can answer the following question.

Journal Write:

20. Did the ball actually curve as it rolled across the turntable? (Hint: compare circles A and B) Use evidence to support your answer.

Resources:

NASA. The NASA Science Files. *The Atmosphere.*
Available: http://whyfiles.larc.nasa.gov/text/kids/Problem_Board/problems/light/sim3.html

PSU. *Coriolis Ball.*
Available: http://www.essc.psu.edu/~pavloski/meteo3/l10/coriolisball.mov

Danish Wind Industry Association. *The Coriolis Force.*
Available: http://www.windpower.dk/tour/wres/coriolis.htm

The Ohio University. David J. Van Domelen. *Getting Around the Coriolis Force.*
Available: http://www.physics.ohio-state.edu/~dvandom/Edu/newcor.html

NOVA Online Adventure. *Global Wind Patterns.*
Available: http://www.pbs.org/wgbh/nova/elnino/now/mapping13llarge.html

NASA JPL. *Gwind.*
Available: http://winds.jpl.nasa.gov/movies/Gwind3_320_cine2x.mov

Fayette State University. Ronald Johnston. *Project NOVA. Module 3. Lesson 3 Coriolis Effect.*
Available: http://www.uncfsu.edu/msec/nova/timmod3d.htm

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 9: CONVECTION CELLS

Estimated Time: Two fifty-minute blocks

Indicator(s) Core learning Goal 1:

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.2.7 The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.

1.3.2 The student will recognize safe laboratory procedures.

1.3.3 The student will demonstrate safe handling of the chemicals and materials of science.

1.3.4 The student will learn the use of new instruments and equipment by following instructions in a manual or from oral direction.

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

Indicator(s): Core Learning Goal 2:

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) - Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

Student Outcome(s):

1. The student will be able to diagram atmospheric convection cells by conducting a laboratory investigation and reading a technical selection.
2. The student will be able to explain how winds moderate weather and climate by analyzing the pattern of global winds.

WHAT DOES THE RESEARCH SAY?

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of

gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.
AAAS. *Benchmarks for Science Literacy*. (1993).

Brief Description:

In this lesson students investigate how uneven heating of the earth causes the formation of convection cells and global winds. Using their knowledge of global winds, students examine how winds influence weather and moderate climates.

Background knowledge / teacher notes:

This lesson focuses on large-scale air circulation within the troposphere. The driving force behind atmospheric circulation is the global distribution of energy. As latitude increases, the amount of incoming solar radiation decreases. Consequently, more solar radiation is received at the equator than at the poles, resulting in a temperature gradient

As previously demonstrated, uneven heating of Earth creates a pressure gradient. The response is movement of the atmosphere; a negative feedback loop is formed. Energy is transferred from the equator to the poles to reduce the pressure gradient. The atmosphere is heated near the equator, and a convection current forms as air rises. The convection box activity will help students visualize this concept. (The smoke from the smoldering wooden splint makes air movement visible.) In the convection box, heated air rises creating an area of low pressure. This simulates the behavior of the atmosphere at the equator. The rising air is replaced by cooler air that moves towards the equator from regions of higher pressure, also demonstrated by the convection box. The merging air masses move inward at a convergence zone.

Because Earth rotates, wind and water do not circulate in a straight line but are deflected. In the Northern Hemisphere, Earth's rotation causes air cells to revolve in a clockwise or anticyclonic direction. This movement is counterclockwise, or cyclonic, in the Southern Hemisphere. Known as the Coriolis effect, this phenomenon is responsible for east-west movements of surface winds.

A satellite image of global winds can be found at NOVA Online Adventure. *Global Wind Patterns.* Available: http://www.pbs.org/wgbh/nova/elnino/now/mapping13llarge.html

Lesson Description:

ENGAGE	Teacher Demonstration: Materials: flashlight, globe Directions: Hold a flashlight aimed (representing the sun) approximately two feet away from the globe. Make sure the flashlight is centered on the equator. Discussion: 1. Do all parts of the earth receive the same amount of solar radiation? *No* 2. Which parts receive more? *Equator* 3. Which parts receive less? *Poles* 4. Why is there more solar radiation at the equator? 5. How would receiving different amounts of solar radiation affect the climate of these areas? *Equator would be warmer; poles colder.* 6. How can we be sure that the amount of solar radiation differs? *We could compare the amount of solar radiation using a light probe or we could compare the temperatures using a temperature probe.* Ask students to hold a temperature probe at the equator and another at the poles. Take a temperature reading after a few minutes. Show a map of global air temperature patterns. Department of Geography University of Oregon. *Temperature.* Available: http://geography.uoregon.edu/envchange/clim_animations/ ***Journal Write:*** 1. What is the relationship between latitude and the amount of solar radiation that reaches Earth? *The further away from the equator the less solar radiation.*

	2. What is the relationship between the area of Earth heated by solar radiation and the temperature within that area? *Generally, the more solar radiation, the higher the temperatures.* 3. What happens to air when it's heated? *It becomes less dense, rises and expands.* Let's examine this more closely.
EXPLORE	Working in groups, students perform a convection box simulation. What Causes Wind? Materials: convection box, matches, candle, wooden splint, aluminum foil Directions: 1. Directly underneath one of the holes, place a small piece of aluminum foil on the bottom of the convection box. (This will prevent wax from spilling in the bottom of the convection box.) 2. Place the candle on the aluminum foil. ***Journal Write:*** 3. Draw a picture of the convection box. 4. Light the candle. Close the front of the convection box. 5. Light a wooden splint. Allow it to burn for several seconds then blow it out. 6. While the wooden splint is still glowing, hold it inside the opening opposite the candle. (See illustration.) <u>Adaptive Strategy</u>: Have a model of the convection box already set up. Model how to light the wooden splint, blow it out and place it in the opening. ***Journal Write:*** 7. On your diagram, trace the movement of smoke generated from the wooden splint. 8. Blow out the candle.

	Journal Write: 9. On your diagram, trace the movement of smoke. 10. Explain why the smoke moves. 11. Keeping in mind that wind is the horizontal movement of air, label the wind(s) in the diagram.
EXPLAIN	Discussion: 1. Describe the path of the smoke. *Smoke from the wooden splint moved down, toward the candle, then rose over the candle.* 2. Why did the smoke move? *The candle caused uneven heating of the air. As the hot air rose, cooler air was drawn in, pulling the smoke with it. This type of movement is called a Convection current.* 3. How does uneven heating generate wind? *As the air is heated, an area of low pressure is generated. This air rises, drawing in cooler air of higher pressure.*
EXTEND	***Journal Write:*** 1. Use observations from the convection box lab and teacher demonstration; predict the direction of atmospheric circulation from the equator to higher latitudes. 2. Draw arrows on the circle/globe representing the movement of large air masses in the atmosphere. Use red arrows to represent warm air, and blue arrows to represent cold air. Materials: diagrams of circle/globe with latitude lines, red and blue colored pencils. <u>Adaptive Strategy</u>: Discuss with the students the direction and color of the arrow at the equator and the poles. Follow one air mass from the equator to the poles. Allow a few groups to share their predictions with the class. Teacher Note: Help students realize that as air moves away from the

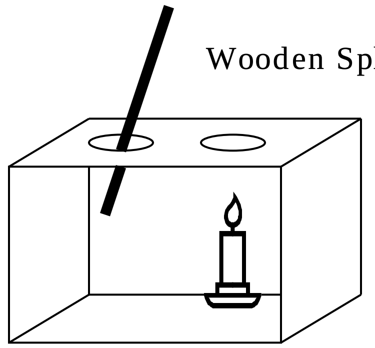
	equator it cools, becomes denser, and sinks back toward the ground where it is warmed and rises again. As cold, dry dense air moves from the poles toward the equator, it is warmed and begins to rise. Discussion: 1. Give students a new globe/circle diagram to record the convection cells. 2. Work with the class to develop the three convection cells. Read in order to describe planetary winds. NASA. *Making Sense of the Weather - Global Wind Patterns.* Available: http://kids.earth.nasa.gov/archive/nino/global.html or Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. pp. 305 – 307. ***Journal Write:*** 1. Draw the three global winds in the Northern hemisphere and in the Southern hemisphere. *Trade winds, Westerlies, Polar Easterlies* 2. How does the Coriolis effect influence the movement of atmospheric circulation in the Southern hemisphere? How do winds influence weather and climate? Encyclopedia of the Atmospheric Environment. *General Circulation.* Available: http://www.doc.mmu.ac.uk/aric/eae/Climate/Older/General_Circulation.html G/T Connection: Physical Geography of Australia. Gene Dayton. *Global Circulation.* Available: http://www.ahs.cqu.edu.au/humanities/geography/52120/trial/global.ht

	m Or other similar text passages. ***Journal Write:*** 1. How do planetary winds moderate weather and climate? *Winds help moderate temperatures by transporting heat and moisture to the poles and cooling off the equator.* 2. How can meteorologist predict what our weather will be like in two or three days? *Look at the weather patterns in California. Our weather generally moves from west to east due to the Westerlies.* INTEREST CENTER Planetary Science. *Energy transport.* Available: http://www.astronomynotes.com/solarsys/s4.htm Winds and Coriolis effect on other planets.
EVALUATE	***Journal Write:*** 1. Draw a diagram showing the global winds and atmospheric convection cells. 2. Explain how global winds moderate climate and influence weather.

Materials:

- Convection box
- Matches
- Candle
- Wooden splint
- Aluminum foil
- Globe
- Flashlight
- Thermometer or CBL temperature probe

What Causes Wind?



Materials: Convection box, candle, matches, wooden splint, aluminum foil

Directions:

1. Directly underneath one of the holes, place a small piece of aluminum foil on the bottom of the convection box. (This will prevent wax from spilling in the bottom of the convection box.)
2. Place the candle on the aluminum foil.

Journal Write:

3. Draw a picture of the convection box.

4. Light the candle. Close the front of the convection box.
5. Light a wooden splint. Allow it to burn for several seconds then blow it out.
6. While the wooden splint is still glowing, hold it inside the opening opposite the candle.

Journal Write:

7. On your diagram, trace the movement of smoke generated from the wooden splint.

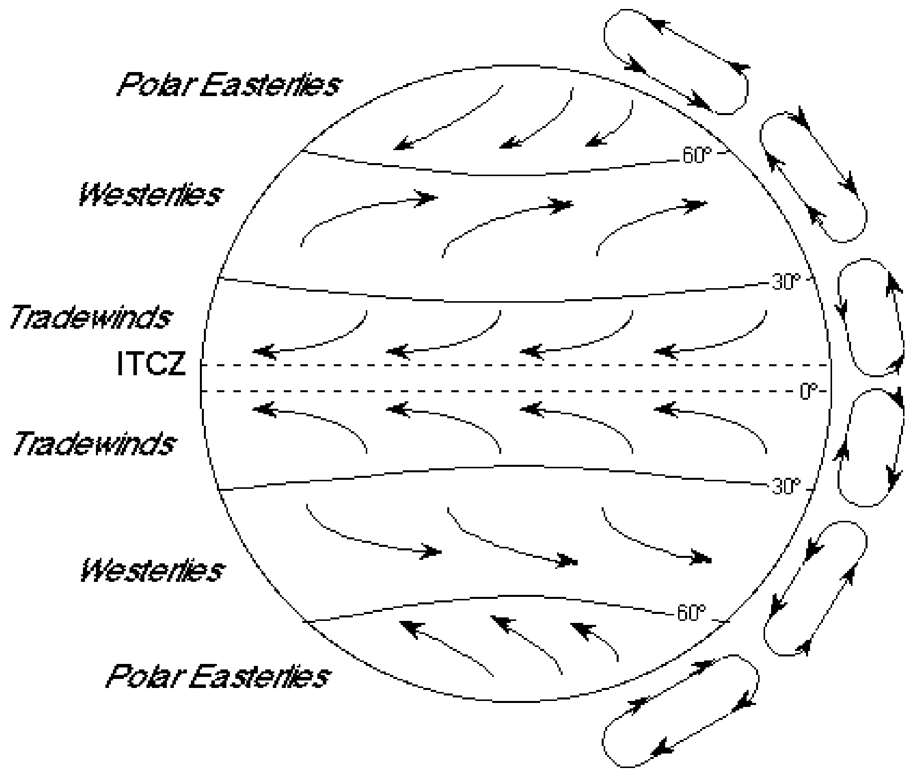
8. Blow out the candle.

Journal Write:

9. On your picture of the convection box, trace the movement of smoke.
10. Why did the smoke move?

11. Keeping in mind that wind is the horizontal movement of air, label the wind(s) in the diagram.

Atmospheric Circulation & Hadley Cells



Earth/Space Systems Science
Unit II: The Atmosphere

Resources:

Encyclopedia of the Atmospheric Environment. *General Circulation.*
Available: http://www.doc.mmu.ac.uk/aric/eae/Climate/Older/General_Circulation.html

Glencoe McGraw-Hill. (2002). Glencoe Earth Science Geology, the Environment and the Universe. pp. 305 – 307.

Physical Geography of Australia. Gene Dayton. *Global Circulation.*
Available: http://www.ahs.cqu.edu.au/humanities/geography/52120/trial/global.htm

NASA. *Making Sense of the Weather - Global Wind Patterns.*
Available: http://kids.earth.nasa.gov/archive/nino/global.html

Department of Geography University of Oregon. *Temperature.*
Available: http://geography.uoregon.edu/envchange/clim_animations/

Department of Geological Services. *Tropospheric Wind Circulation.*
Available: http://seis.natsci.csulb.edu/rbehl/winds.htm

INTEREST CENTER
Planetary Science. *Energy transport.*
Available: http://www.astronomynotes.com/solarsys/s4.htm

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 10: PRESSURE GRADIENTS

Estimated Time: One fifty-minute block

Indicator(s): Core Learning Goal 1:

1.4.2 The student will analyze data to make predictions, decisions, or draw conclusions.

1.5.5 The student will create and/or interpret graphics (scale drawings, photographs, digital images, etc.).

1.5.9 The student will communicate conclusions derived through a synthesis of ideas.

1.6.4 The student will manipulate quantities and/or numerical values in algebraic equations.

Indicator(s): Core Learning Goal 2

2.3.1 The student will describe how energy and matter transfer affect Earth systems. Assessment limits (at least) - Atmospheric circulation (heat transfer systems – conduction/convection/radiation, phase change, latent heat, pressure gradients, general global circulation, Coriolis effect)

Student Outcome(s):

The student will be able to evaluate the relationship between pressure gradients and wind speed by analyzing weather maps.

WHAT DOE S THE RESEARCH SAY?

Students also need to learn how to analyze evidence and data. The evidence they analyze may be from their investigations, other students' investigations, or databases. Data manipulation and analysis strategies need to be modeled by teachers of science and practiced by students. Determining the range of the data, the mean and mode values of the data, plotting the data, developing mathematical functions from the data, and looking for anomalous data are all examples of analyses students can perform. Teachers of science can ask questions, such as "What explanation did you expect to develop from the data?" "Were there any surprises in the data?" " How confident do you feel about the accuracy of the data?" Students should answer questions such as these during full and partial inquiries. National Research Council, *National Science Education Standards* (1996).

Brief Description:

In this lesson, students create an isobar pressure map from raw pressure data and use their maps to create transect lines of pressure gradients. Based on their knowledge of atmospheric pressure gradients, they predict wind speed.

Background knowledge / teacher notes:

Atmospheric or barometric pressure is the weight of the atmosphere. High pressure is generally associated with fair weather and low pressure is generally associated with cloudy skies and precipitation. High pressure is usually caused by cooler air moving down toward Earth's surface and low pressure is generally caused by warm air rising. The lowest pressure areas on Earth are the centers of hurricanes and tornadoes.

As in most natural systems where there is a tendency toward equilibrium, air moves from high to low concentrations; in other words, air moves from areas of high to low pressure. The speed of the wind is determined by the pressure gradient. Wind speed is directly proportional to the size of the pressure gradient.

Pressure gradient is the change in pressure over distance. It can be determined mathematically by using the formula:

(highest pressure-lowest pressure) / distance between highest and lowest pressures

Students can locate the centers of the low and high-pressure areas by generating an isobar (lines of equal barometric pressure) map. Isoline is a generic term that is used to mean a line of equal numerical value.

Basic rules for generating isolines are as follows:

- Each line can only represent one numerical value (e.g., 1004 mb).
- The area on one side of the line should be of a higher value than the value of the line and the area on the other side of the line should be of a lower value than the value of the line.

- Isolines always have a uniform interval (the interval for isobars is generally 4 millibars).
- Spacing of the lines is dictated by the data. In most cases, the exact value the line represents will need to be estimated from surrounding data. For example, if weather station A reports 1002mb and weather station B reports 1006mb, the 1004mb line would pass between the two stations.
- Isolines always form closed loops, but many maps do not cover enough area to show the entire closed loop. In this case, the line may end at the edge of the map in one location and begin at the edge of the map in another location.
- Isolines may never touch or cross one another. (There can never be more than one pressure value in any given location).

Real time daily pressure data (along with a professionally developed isobar map) can be found in the "surface" data table of the DataStreme web site. Visit The American Meteorological Society. *The DataStreme Project.* Available: http://www.ametsoc.org/dstreme/index.html. If that site is unavailable there a number of mirror sites, e.g., http://www.comet.ucar.edu/dstreme/.

Teacher Note: Once the pressure values and isobar maps are located, print them out in a landscape view.

Lesson Description:

ENGAGE	Show students a topographic map with an obvious hill or mountain feature and ask them to draw an image of what the feature might look like. TopoZone.com. *Welcome to the TopoZone.* Available: http://www.topozone.com/ Teacher Note: Pike's Peak in Colorado provides a good topographic map for this activity. Discussion: Have a few students share their drawings. Encourage them to explain how they decided what to draw. 1. How is gradient is represented on the map? *Lines or circles. The closer lines are, the steeper the gradient.*

	2. How does the gradient of a hill affect the speed of a ball rolling down the hill?
EXPLORE	Weather maps are available in the local paper or at many websites. USAToday. *Weather*. Available: http://www.usatoday.com/weather/forecast/forecast-redirect.htm Discussion: Examine a weather map with areas of high and low pressure labeled. 1. What do H and L represent? *High and low pressure systems* 2. Why do meteorologist keep track of Highs and Lows? *They indicate the type of weather or changes in weather. High pressure is generally associated with fair weather and low pressure is generally associated with cloudy skies and precipitation.* 3. Does a High really have high pressure? Provide students with a barometric pressure map. Barometric pressure maps can be found at The Weather Channel. *The Weather Channel Index.* Available: http://www.weather.com Draw isobars on pressure data map by connecting equal pressure points. Teacher Note: Review the rules for connecting isolines. Model how to connect lines. Basic Rules for Drawing Isolines 1. Each line can only represent one numerical value (e.g., 1004 mb). 2. The area on one side of the line should be of a higher value than the value of the line and the area on the other side of the line should be of a lower value than the value of the line. 3. Isolines always have a uniform interval (the interval for isobars is generally four millibars).

	4. Spacing of the lines is dictated by the data. In most cases, the exact value the line represents will need to be estimated from surrounding data. For example, if weather station A reports 1002mb and weather station B reports 1006mb, the 1004mb line would pass between the two stations. 5. Isolines always form closed loops, but many maps do not cover enough area to show the entire closed loop. In this case, the line may end at the edge of the map in one location and begin at the edge of the map in another location. 6. Isolines may never touch or cross one another. (There can never be more than one pressure value in any given location). Label high and low-pressure areas.
EXPLAIN	Discussion: Technical Connection: : View the animation of a pressure gradient force at University of Illinois. *Pressure Gradient Force*. Available: http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/fw/pgf.rxml Knowing that air (wind) moves from high to low pressure, draw arrows showing the direction of winds on your map. ***Journal Write:*** 1. How are topographical maps and barometric pressure maps similar? 2. How is the movement of wind similar to a ball rolling down a hill? 3. Predict where wind speeds will be the highest.
EXTEND	Materials: pressure map, ruler, graph paper Construct a cross-sectional profile. 1. On the barometric pressure map, draw a straight line connecting a high-pressure (H) to a low-pressure (L).

2. Draw a line on the graph paper. Fold the graph paper along the line.
3. Place the fold in the graph paper next to the straight line on the map.
4. Start at either the high or the low and mark off every place an isoline crosses the straight line.
5. Graph the pressure of each isoline.
6. Connect the pressures. This will generate a cross-sectional profile of the barometric pressures.

Adaptive Strategy: Do a think-aloud on how to connect the pressure systems. Model how to draw a cross-sectional profile.

Journal Write:

Calculate the pressure gradient along each transect line using the formula:

Change in pressure / distance

Adaptive Strategy: Allow students to use calculators.

Journal Write:

Wind speed is directly proportional to the size of the pressure gradient. Where are wind speeds the greatest? Use your data and the trends shown on your graph to support your answer.

G/T/Technical Connection:

Use current daily pressure data from The American Meteorological Society. *The DataStreme Project.*

Available: http://www.ametsoc.org/dstreme/index.html

Or a comparable map may be used.

1. Scroll down to Surface chart, click on "Pressure" to get a map showing current pressures.
2. Go back to Surface chart and click on "Isobars & Pressure" to get the correct isobaric drawing for the day.

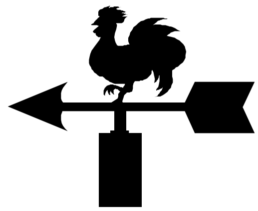
	3. Create isobar maps ***Journal Write:*** 1. Label the high and low pressure centers 2. Predict local wind conditions. INTEREST CENTER: This website explains air pressure and factors that affect it. NASA. *It's A Breeze - How Air Pressure Affects You.* Available: http://kids.earth.nasa.gov/archive/air_pressure/index.html
EVALUATE	Provide students with a new barometric pressure map. ***Journal Write:*** 1. Draw arrows on the map indicating the direction of wind. 2. Circle the location where the wind speeds will be the highest. 3. Explain how meteorologists predict wind speed based on pressure gradients.

Materials:

- Topographic map
- Pressure data maps
- Ruler
- Graph paper
- Calculators
- Backup “real time” isobar/ pressure data maps

Earth/Space Systems Science
Unit II: The Atmosphere

Basic Rules for Drawing Isolines



1. Each line can only represent one numerical value (e.g., 1004 mb).

2. The area on one side of the line should be of a higher value than the value of the line and the area on the other side of the line should be of a lower value than the value of the line.

3. Isolines always have a uniform interval (the interval for isobars is generally four millibars).

4. Spacing of the lines is dictated by the data. In most cases, the exact value the line represents will need to be estimated from surrounding data. For example, if weather station A reports 1002mb and weather station B reports 1006mb, the 1004mb line would pass between the two stations.

5. Isolines always form closed loops, but many maps do not cover enough area to show the entire closed loop. In this case, the line may end at the edge of the map in one location and begin at the edge of the map in another location.

6. Isolines may never touch or cross one another. (There can never be more than one pressure value in any given location).

Earth/Space Systems Science
Unit II: The Atmosphere

Construct a cross-sectional profile.

1. On the barometric pressure map, draw a straight line connecting a high-pressure (H) to a low-pressure (L).

2. Draw a line on the graph paper. Fold the graph paper along the line.

3. Place the fold in the graph paper next to the straight line on the map.

4. Start at either the high or the low and mark off every place an isoline crosses the straight line.

5. Graph the pressure of each isoline.

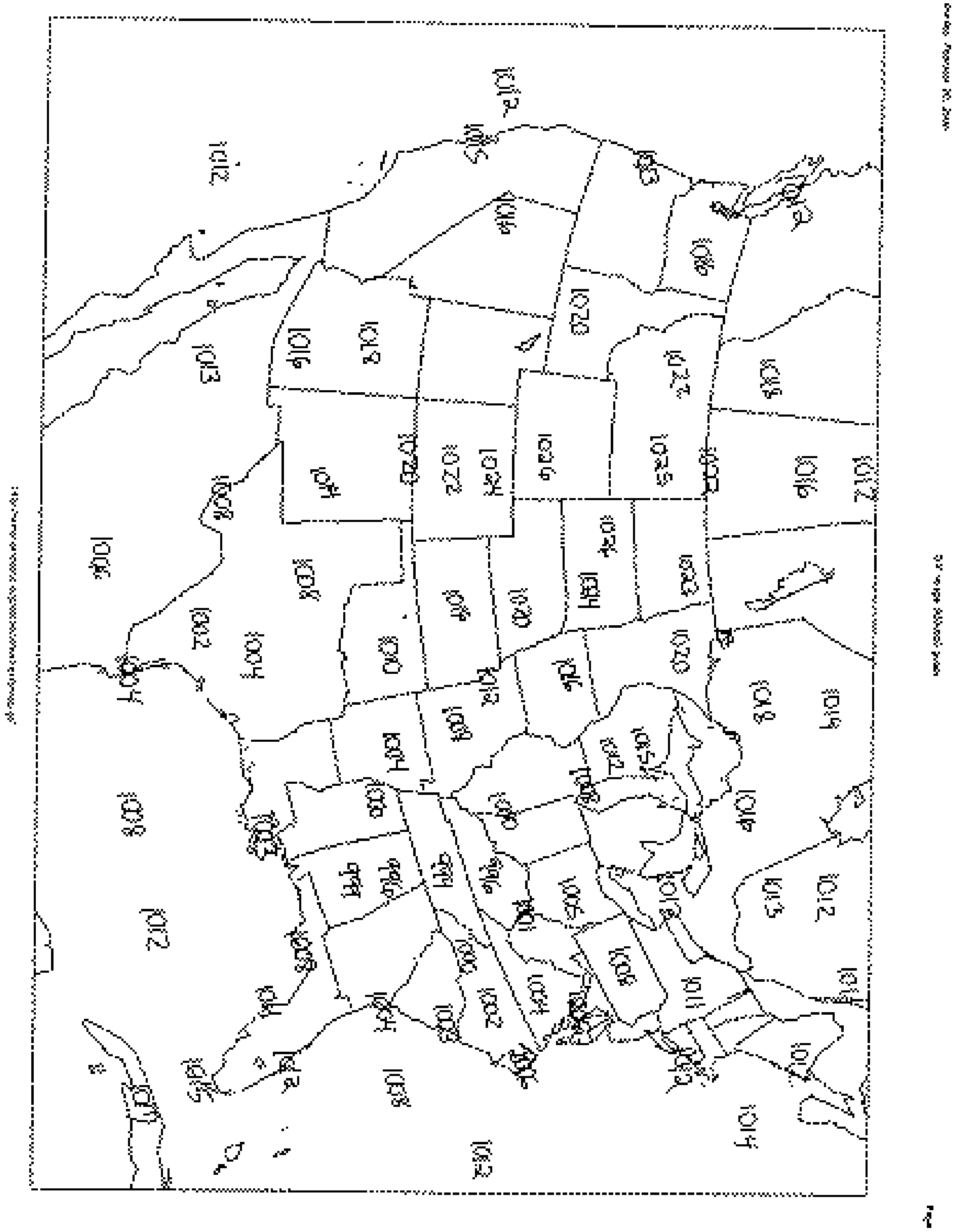
6. Connect the pressures. This will generate a cross-sectional profile of the barometric pressures.

Journal Write:

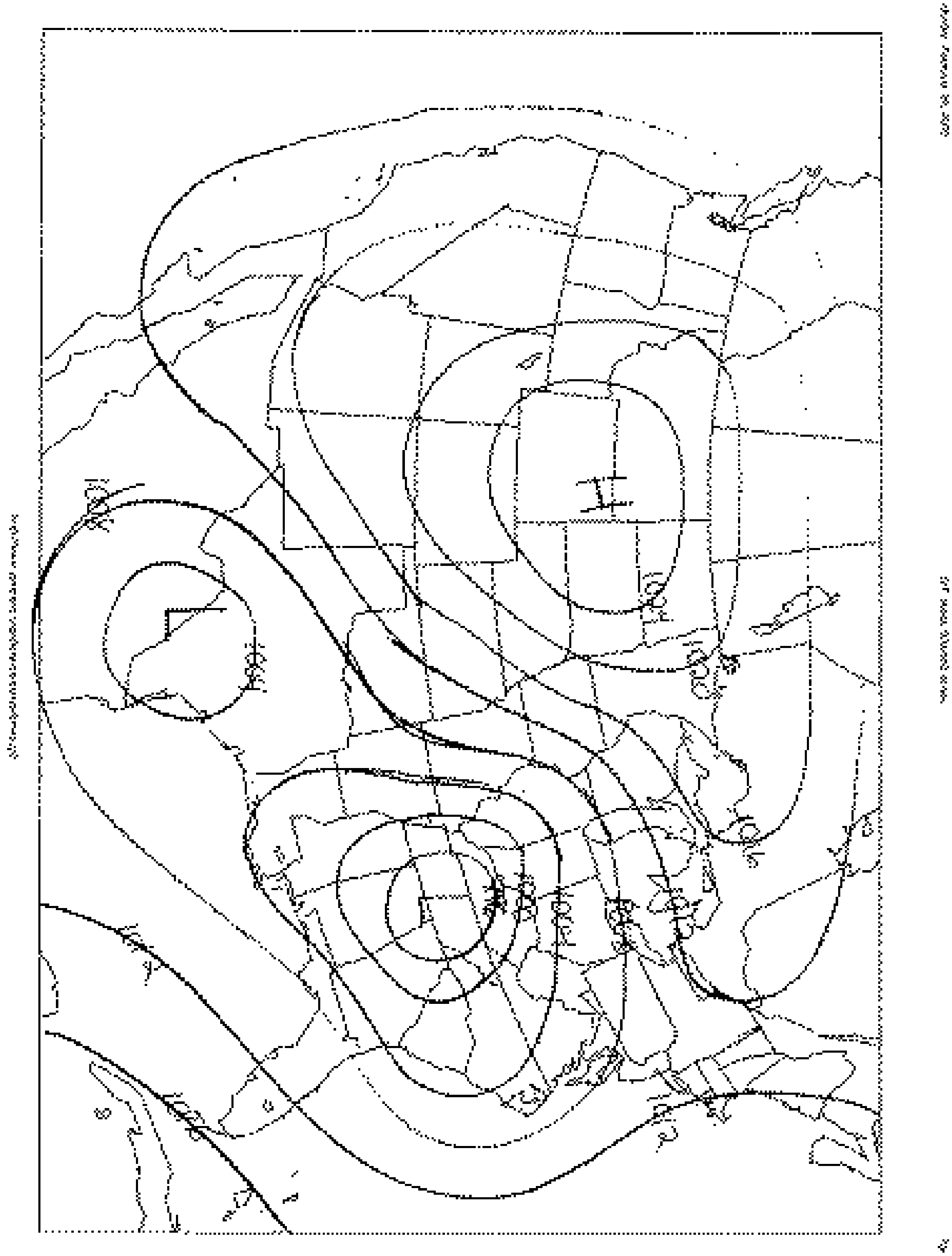
Calculate the pressure gradient along each transect line using the formula:

Change in pressure / distance

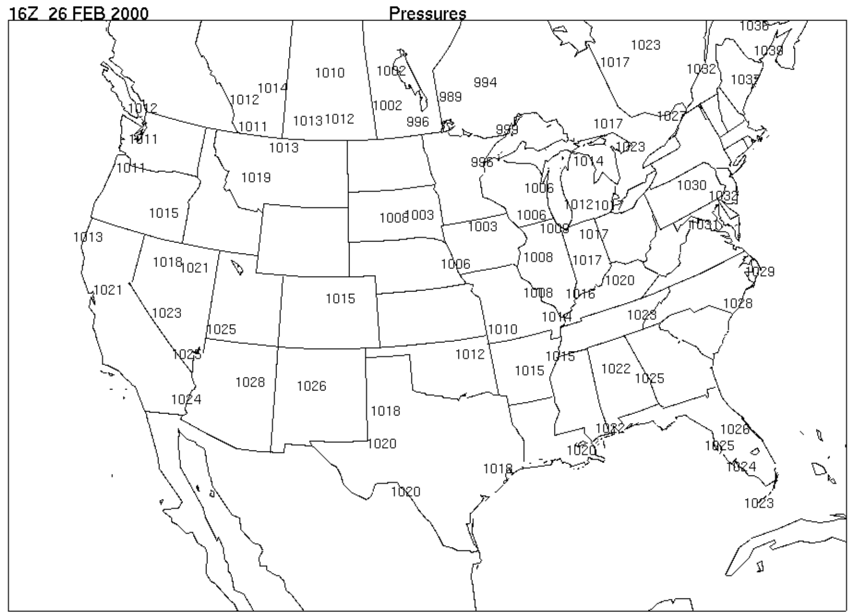
Student data map:

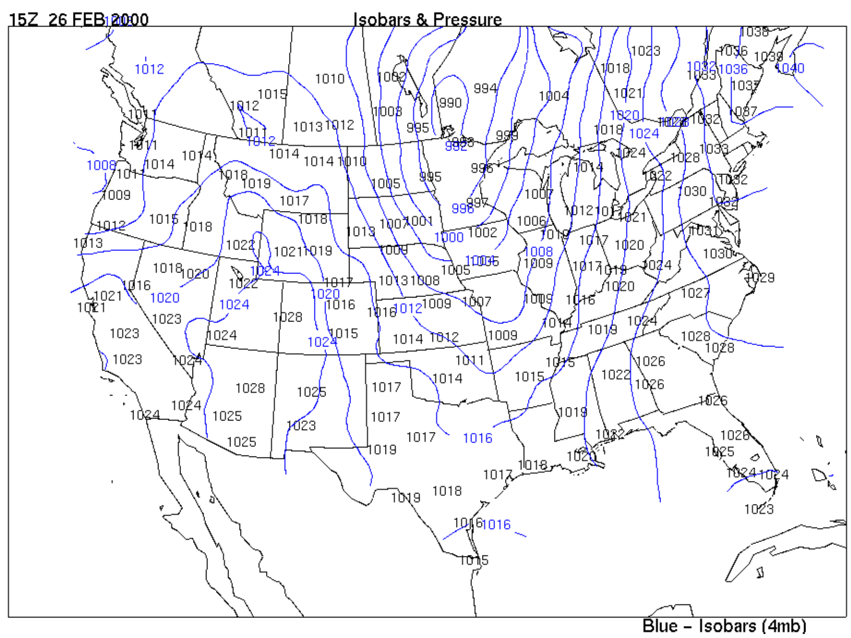


Complete teachers' copy of data map.



Back up data and isobar maps:





Resources:

The American Meteorological Society. *The DataStreme Project.*

Available:

http://www.ametsoc.org/dstreme/index.html or http://www.comet.ucar.edu/dstreme/

University of Illinois. *Pressure Gradient Force*.

Available: http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/fw/pgf.rxml

USAToday. *Weather.*

Available: http://www.usatoday.com/weather/forecast/forecast-redirect.htm

The Weather Channel. *The Weather Channel Index.*

Available: http://www.weather.com

TopoZone.com. *Welcome to the TopoZone.*

Available: http://www.topozone.com/

INTEREST CENTER:

NASA. *It's A Breeze - How Air Pressure Affects You.*

Available: http://kids.earth.nasa.gov/archive/air_pressure/index.html

Earth/Space Systems Science
Unit II: The Atmosphere

Lesson 11: LATENT HEAT AND STORMS

Estimated Time: One fifty-minute block

Indicator(s) Core learning Goal 1:

1.1.1 The student will recognize that real problems have more than one solution and decisions to accept one solution over another are made on the basis of many issues.

1.1.2 The student will modify or affirm scientific ideas according to accumulated evidence.

1.3.4 The student will learn the use of new instruments and equipment by following instructions in a manual or from oral direction.

1.4.3 The student will use experimental data from various investigators to validate results.

1.4.8 The student will use models and computer simulations to extend his/her understanding of scientific concepts.

1.7.2 The student will identify and evaluate the impact of scientific ideas and/or advancements in technology on society.

Indicator(s): Core Learning Goal 2:

2.1.2. The student will describe the purpose and advantage of current tools, delivery systems and techniques used to study the atmosphere, land and water on Earth (Delivery systems – satellite, ground based.)

2.3.1. The student will describe how energy and matter transfer affect Earth systems (Atmospheric circulation – phase change, latent heat.)

Student Outcome(s):

1. The student will be able to explain how latent heat contributes to the formation of storms by examining the life cycle of a thunderstorm.
2. The student will be able to describe the role of satellites in meteorology by analyzing satellite imagery.

Earth/Space Systems Science
Unit II: The Atmosphere

Brief Description:

Students look at real-time satellite, radar, and derived imagery to study the growth and development of thunderstorms. They also examine the role of phase changes and latent heat in atmospheric processes such as thunderstorms.

Background knowledge / teacher notes:

The GOES (Geostationary Operational Environmental Satellites) meteorological satellites have become an integral component of weather forecasting. Currently, the GOES-East Satellite and the GOES-West Satellite provide coverage of North America and South America and the surrounding water bodies. These satellites are engineered, constructed, and launched by the National Aeronautics and Space Administration (NASA). After testing and obtaining operational status, the control is turned over to the National Oceanic and Atmospheric Administration (NOAA). The National Weather Service (NWS), an organization within NOAA, is responsible for providing governmental and commercial agencies with necessary meteorological information. Satellite images and data are used regularly to analyze the current weather systems as well as predict future weather. The NWS is also responsible for issuing all watches and warnings for severe weather.

Latent heat associated with phase changes plays a vital role in the evolution of thunderstorms, as well as many other atmospheric processes. It takes energy (usually in the form of heat) to raise the temperature of water. It takes considerably more energy to cause matter to change to higher temperature phases (from solid to liquid, and liquid to gas.) The Law of Conservation of Energy tells us that this energy is now stored in the matter as potential energy (unless you want to quibble, and say it is kinetic energy contained in the motion of the molecules.) This energy is called *latent energy* (or latent heat.) The energy is released when the temperature of the matter's falls. Considerably greater energy is released when matter changes to a lower temperature phase (gas to liquid, liquid to solid.)

The energetics of phase change and latent heat have easily visualized and -explained analogies, such as rechargeable batteries and the cell's ATP/ADP cycle.

Water is a unique substance when it comes to phase changes and latent energy:
It is the only atmospheric component that undergoes both phases changes (liquid/solid, gas/liquid) within the normal temperature range of the atmosphere.
Therefore, it is the only atmospheric component that can be present as gas, liquid, or solid.
Water requires more energy to change its temperature than other common substances and takes in or releases more energy during its phase changes than other common substances.

Lesson Description:

ENGAGE	Students work in pairs. Directions: 1. Recall a typical summer afternoon thunderstorm. 2. Think about what the storm was like. 3. Describe the storm to your partner. Adaptive Strategy: Give the students a few key words to describe e.g., clouds, wind, changing temperatures, rain, thunder, lightning, etc. Or read the description of a thunderstorm. Windows to the Universe. *Thunderstorms.* Available: http://windows.arc.nasa.gov/cgi-bin/tour_def/earth/Atmosphere/tstorm.html Discussion: Encourage a few students to share their story with the class. What do most thunderstorms have in common?
EXPLORE	Life Cycle of a Thunderstorm Technical Connection: View the simulation of a thunderstorm. WeatherEye. *Thunderstorms.* Available: http://weathereye.kgan.com/expert/tstorms/stages.html Simulation of activity inside a thunderstorm.

	Journal Write: Use a graphic organizer such as a sequence chart to describe the stages of the thunderstorm. Technical Connection: : View the satellite imagery of thunderstorms. NWS. Buffalo.NOAA. *Thunderstorm Animation.* Available: http://www.wbuf.noaa.gov/storm.htm NASA Educational Brief Subject: *GOES Satellite. Satellite Imagery*. Available: http://edmall.gsfc.nasa.gov/inv99Project.Site/Pages/science-briefs/ed-mccook/ed-goes.html ***Journal Write:*** Describe some of the information scientists collect using satellite images of thunderstorms.
EXPLAIN	Discussion: 1. What are the stages of a thunderstorm? 2. What are their characteristics? 3. Think of the water cycle. What parts of the water cycle are illustrated in a thunderstorm? Write student responses on the board or overhead. Read about phase changes. USA Today. The Phase Changes of Water. Available: http://www.usatoday.com/weather/wlatent1.htm Adaptive Strategy: Have student focus on the opening paragraph. Illustrate latent heat by highlighting the latent heat of condensation.

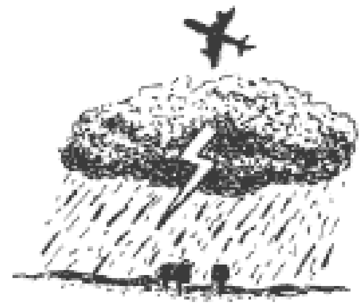
	Journal Write: What is latent heat? *When water changes from one phase to another, energy is either absorbed or released into the air. This hidden energy is known as latent heat.*
EXTEND	How does latent heat power storms? Read to be informed about latent heat and storms: USA Today. *Latent Heat Provides Fuel for Storms.* Available: http://www.usatoday.com/weather/wlatent.htm Or Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Moisture in the Atmosphere. Latent Heat." p. 286. Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Thunderstorms." pp. 329 – 330. Or other similar text passages. ***Journal Write:*** 1. How does latent heat contribute to the formation of a storm? 2. In the formation of the thunderstorm, water vapor condenses to form water droplets. This releases heat. How does this heat affect the thunderstorm? Technical Connection: : Learn how to use satellite data to spot thunderstorms. Unisys.Weather. *Satellite Image Details.* Available: http://weather.unisys.com/satellite/details.html Make a graphic organizer to record information about satellite imagery of thunderstorms.

	Now examine thunderstorm activity in your area. NOAA. GOES. *Geostationary Satellite Server.* Available: http://www.goes.noaa.gov/ Teacher Note: If there is no thunderstorm activity in your area, simply select a different area to examine. 1. From the chart choose **East CONUS.** (East satellite image of the continental US.) 2. Click on **Visible** 3. Look for thunderstorms. Refer to your graphic organizer for clues to help interpret the image. 4. Return to the main page by clicking the Back button. 5. Look at the same image in the **Water Vapor** channel. 6. Look for thunderstorms. 7. Return to the main page 8. On the left hand side is a menu of GOES imagery and products. 9. Select Color Enhanced Imagery 10. Look for thunderstorms. ***Journal Write:*** 1. Have you found any possible areas of thunderstorm activity? 2. What evidence do you have to support this conclusion? Technical Connection: 1. Examine a current Radar image. NOAA. National Weather Service. *National Doppler Radar Sites.* Available: http://weather.noaa.gov/radar//loop/DS.78ohp/si.kdox.shtml 2. From the side bar select a time-lapse loop. 3. Examine local conditions. Wunderground.com. *Weather.* Available: http://www.wunderground.com/US/MD/Baltimore.html

	Journal Write: Compare the actual ground observations (local conditions) with your satellite and radar imagery. Discussion: What difference have these satellite and Doppler radar images made in our lives? *More accurate weather forecasts, early warning system of tornados…*
EVALUATE	***Journal Write:*** Describe the life cycle of a thunderstorm: · explain the role of latent heat. · identify the phase changes that occur in the storm.

Earth/Space Systems Science
Unit II: The Atmosphere

Thunderstorms!!



Directions:

Visit the following website NOAA. GOES. *Geostationary Satellite Server.*

Available: http://www.goes.noaa.gov/

1. From the chart choose **East CONUS.** (East satellite image of the continental US.)
2. Click on **Visible**
3. Look for thunderstorms. Refer to your graphic organizer for clues to help interpret the image.
4. Return to the main page by clicking the Back button.
5. Look at the same image in the **Water Vapor** channel.
6. Look for thunderstorms.
7. Return to the main page
8. On the left hand side is a menu of GOES imagery and products.
9. Select Color Enhanced Imagery
10. Look for thunderstorms.

Journal Write:

1. Have you found any possible areas of thunderstorm activity?

2. What evidence do you have to support this conclusion?

Resources:

NOAA. GOES. *Geostationary Satellite Server.*
Available: http://www.goes.noaa.gov/

NASA Educational Brief Subject: *GOES Satellite. Satellite Imagery.*
Available: http://edmall.gsfc.nasa.gov/inv99Project.Site/Pages/science-briefs/ed-mccook/ed-goes.html

Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Moisture in the Atmosphere. Latent Heat." p. 286.

Glencoe. (2002). Earth Science: Geology, the Environment, and the Universe. "Thunderstorms."pp. 329 – 330.

USA Today. *Latent Heat Provides Fuel for Storms.*
Available: http://www.usatoday.com/weather/wlatent.htm

NOAA. National Weather Service. *National Doppler Radar Sites.*
Available: http://weather.noaa.gov/radar//loop/DS.78ohp/si.kdox.shtml

USA Today. The Phase Changes of Water.
Available: http://www.usatoday.com/weather/wlatent1.htm

Unisys.Weather. *Satellite Image Details.*
Available: http://weather.unisys.com/satellite/details.html

Windows to the Universe. *Thunderstorms.*
Available: http://windows.arc.nasa.gov/cgi-bin/tour_def/earth/Atmosphere/tstorm.html

WeatherEye. *Thunderstorms.*
Available: http://weathereye.kgan.com/expert/tstorms/stages.html

NWS. Buffalo.NOAA. *Thunderstorm Animation.*
Available: http://www.wbuf.noaa.gov/storm.htm

Wunderground.com. *Weather.*
Available: http://www.wunderground.com/US/MD/Baltimore.html